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Technical Report

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DEVELOPMENT OF A COMPUTERIZED DATA BASE TO MONITOR WHEELED VEHICLE CORROSION

DAAE07-86-C-R094

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A computerized data base program was developed and utilized to monitor corrosion of wheeled vehicles through on site inspection at three field locations over an 18 month period. Vehicle inspection guidelines with corrosion stage levels are discussed. Spare part storage and handling was evaluated at each site. Cost analysis and data manipulation for scaled up operation of the Corrosion Data Base Monitorship Program is described. Failure analysis of field unit supplied parts was performed and reported. Continued sample data collection will result in improved cost and logistical control of future wheeled vehicle maintenance expenditures.

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PREFACE

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  707th Maintenance Bn
  7th infantry Division

- Neu Ulm, West Germany
  CPT Harvey Harmon
  ACofS G4
  56th Field Artillery Bde

- Schofield Barracks, Hawaii
  MSG Jerry Morton
  ACofS G4
  25th Infantry Division

Their efforts in organizing and Coordinating our inspection visits were vital to the success of our investigation.

Finally, to the U.S. Army and civilian maintenance personnel who keep our Tactical Wheeled Vehicles in a state of readiness. Their cooperation and insight has assisted our inspection team in understanding the scope and magnitude of the "great red menace" that uncontrolled corrosion can be.

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1.0. INTRODUCTION

The purpose of this program was to assist the Army Materiel Command (AMC) in their efforts to identify the scope and magnitude of the corrosion problem, as it related to tactical wheeled vehicles.

In 1985, the Commanding General of AMC issued a Commander's Guidance Statement on Corrosion Prevention and Control (CPC). This statement, in essence, committed all major subcommands within AMC to quantify the magnitude of the corrosion problem, as well as address the necessary corrective actions to prevent and control corrosion throughout the tactical and combat vehicle fleets.

In compliance with these directives for CPC, this program was developed to identify and monitor the progressive nature of the various forms of corrosion attack observed on selected tactical vehicles. As no recording system previously existed solely for the identification of corrosion as a function of useful service life, safety, reliability, or maintenance requirements, it was necessary to first accurately define the scope and magnitude of the corrosion problem.

It is intended that the observations made within this investigation be utilized to: (1) incorporate corrosion preventive concepts into future vehicle designs; (2) develop maintenance procedures to prevent and control corrosion on existing vehicles; (3) permit retrofit design improvements for replacement components; and (4) alert the Army Supply System to projected replacement part needs on supply logistics and overall cost.

2.0. OBJECTIVES

The primary objective of this program was to identify and record evidence of corrosion observed on High Mobility Multipurpose Wheeled Vehicle's, (HMMWV's); 5-Ton Truck (5-Ton); & Commercial Utility Cargo Vehicles, (CUCV's). Three inspections of the vehicles took place over an 18 month period, on location in Germany, California and Hawaii. The resulting data was processed and entered into a specifically designed data base computer program to provide for monitoring of part corrosion with respect to geographical location, time in service, and expected component lifetimes.

Secondary objectives included the inspection of packaging and storage of spare parts at field locations and the failure analysis of failed parts returned from these sites.

3.0 CONCLUSIONS

- Field inspection of motor vehicles is a practical means of assessing the progressive costs of corrosion.

- A Computer data base system can be used to monitor part corrosion history and progress.

- Projected savings with hand-held data collection unit (HDCU) suggest its continued development.

- Eleven percent of failed parts examined were caused by corrosion.

- Original packaging of spare parts is generally satisfactory for indoor storage.

4.0 RECOMMENDATIONS

- Continue the effort to make newly acquired tactical vehicles as corrosion resistant as possible. This would include accelerated vehicle testing, sample data collection, and technical evaluation of ongoing field problems.

- Standardize and use rust proofing and undercoating processes at the source of manufacture and require reapplication of these materials after accidents or local vehicle modifications.

- Develop an Army-wide standard of corrosion protection for those unprotected vehicles currently in the field. Further, insure that this standard is maintained by the prudent use of on- site inspectors during contracted rustproofing application.

- Establish for each type of tactical vehicle a "lead vehicle" policy to give an early indication of corrosion problems and/or component failures. Established by geographical area (determined by corrosion susceptibility) and monitored by AMC, each "lead vehicle" would be utilized (dispatched, TR'ed, etc.) to the maximum extent possible.

- Modify vehicle log books and organizational maintenance records to facilitate capturing corrosion-related maintenance data. Add a section to vehicle manuals that will educate the driver on the identification, prevention, and control of corrosion related problems.

- Continue sample data collection to the end that corrosion losses are fully reported, quantified, and given value. A field loss not reported didn't happen.

5.0 DISCUSSION

5.1. Background-Vehicle Corrosion

5.1.1. What is Corrosion? The word corrosion is derived from the Latin word " corrodere," which means to gnaw away. Indeed the dictionary definition is a process in which a solid, especially a metal, is eaten away and changed by a chemical action, in the presence of water by an electrolytic process.

Corrosion is actually the unwanted or unexpected degrading of metal surfaces and is something to be avoided. This report details an investigation designed to quantify the degradation of wheeled motor vehicles in service due to this gnawing away of metal.

5.1.2. Types of Corrosion. Corrosion is typically separated into two classifications: general or uniform corrosion and localized corrosion.

5.1.2.1. General Corrosion. General corrosion is the most common form of corrosion, which exhibits a more or less uniform attack over a rather large area, and it may occur in a variety of environments. It is more predictable and can be controlled by using more suitable materials: protective coatings, inhibitors or a combination of these expedients. Typical examples of general corrosion are as follows:

- Rusting of unprotected steel in almost any outdoor environment.
- Blistering or loss of paint due to improper preparation of the steel surface prior to painting.
- Uniform pitting of untreated aluminum in a seashore environment.
- White rusting of galvanized steel in an industrial or salt-air environment.

In general corrosion , the rate of attack is very slow. The metal becomes thinner and eventually fails.

5.1.2.2. Local Corrosion. Localized corrosion affects smaller areas of the metal surface, and the rate of penetration in the affected area can be very fast. In many cases, it remains undetected for long periods of time. There are many types of localized corrosion including: galvanic, crevice (concentration cell), pitting, intergranular, stress, erosion, and selective leaching. These types of corrosion are considerably more difficult to predict. They are also localized. Attack is limited to specific areas or parts of a structure. As a result, they tend to cause unexpected or premature failure of the vehicle component.

5.1.3. Causes of Corrosion.

5.1.3.1. Cell Formation. Most corrosion is an electrical phenomenon, much like a series of small batteries or cells. Corrosion of the vehicle is a result of the flow of electricity from one region of the metal not well oxygenated (which acts as a negative electrode) to another region plentifully supplied with oxygen (which is the positive electrode) in the presence of water or an electrolyte. The smaller oxygen denuded area is the region which corrodes. This potential difference, or voltage of these little batteries or cells, is due to the difference in the oxygen availability at the point of attack.

Differential aeration cells occur at all places where there is a difference in the availability of oxygen and can only operate in the presence of a moist environment. They can be formed at the following typical locations:

- Areas holding road dirt, which restricts drying.
- Weld joints and metal folds holding stagnant water.
- Breaks or holidays in painted surfaces.
- Beneath partially adherent coatings.
- At threaded- screw sections.

5.1.3.2. Effects of Salt. Corrosion cells become more active when exposed to ocean spray or road salt. The salt, mixed with dirt, acts to attract moisture from the atmosphere by artificially increasing the relative humidity of its immediate environment. The area is wetted earlier as the relative humidity rises and remains wet for a longer period after the relative humidity falls. Road deicing salt, NaCl, will not start to dry out until the relative humidity falls to 76 percent.

Salt increases the conductivity of the corrosion cell, thus providing for more agresive action. It also reduces the surface tension of water, which allows it to move into small, restricted areas, such as metal folds and joints. In moist, but drying conditions, the salts dry out but will be concentrated in the last remaining liquid to evaporate. This is usually at areas where drying is restricted. The presence of chlorides will also destroy the passive oxide film on steel.

5.1.3.3. Effects of Industrial Pollutants. The principal industrial pollutants are sulfur dioxide, hydrogen sulfide and airborne chlorides. These materials, borne by rain or condensation as evening dew, act to directly increase corrosion by catalytic action. The concentration of these aggresive gases is much greater in the winter.

5.1.4 Prevention Techniques. This data base program is actually an evaluation of the various corrosion prevention systems and methods which were applied to the wheeled vehicles when they were manufactured. The corrosion cell will not work if the flow of electrons is stopped. If there is no water environment outside the metal, there is no corrosion.

5.1.4.1. Paint Films. If the metal surface is isolated from the electrolyte (water containing road salts, etc., in solution) by using a physical barrier such as a paint film, corrosion will not take place. However, a paint film is permeable to both water and oxygen, and does not function when kept wet for a long period, as in the case of water-saturated mud. Paint performs three functions:

- Provides a pigment to color the surface.

- Provides a barrier to isolate the metal from the environment.

- Ensures that the steel surface has equal replenishment of oxygen over the whole surface.

The best of paint films, with good surface preparation, primer, undercoat and top coat, will not eliminate corrosion, but will protect the base metal in mildly corrosive atmospheric environments for reasonable periods of time.

5.1.4.2. Barrier Coatings of Metal. The coating of the steel surface, with a metal such as zinc, offers protection by isolating the metal from the atmosphere. It also provides protection by sacrificial corrosion of the zinc, which produces a white corrosion product which is more acceptable than the deep brown color of rust. Its protection is directly dependent on thickness and environment. The superior corrosion resistance of zinc is due to its ability to form a dense and adherent corrosion product which acts as a barrier to further corrosion.

Zinc and cadmium are plated to small steel components. Cadmium has similar properties to zinc and its effectiveness is dependent on thickness.

5.1.4.3. General suggestions to stop corrosion:

- Keep the vehicle dry and free of stagnant water traps.
- Use paint films and maintain them.
- Keep the vehicle clean and free of chloride containing dirt accumulations.

Basic resource for this section:

McArthur Hugh, "Corrosion Prediction and Prevention in Motor Vehicles", Halsted Press: John Wiley & Sons, New York, 1988

5.2. Program Content and Outline

This program is a continuation of Phase I SBIR Project (DAAE07-85-6-R087) for the Department of the Army TACOM. This final report presents the results of contract efforts for the period 23 September 1986 to 30 September 1989.

The program will be presented under the following major work sections:

- Field inspection guideline development and data acquisition.
- Field inspection training manual.
- Computer data base development and instruction manual.
- Projected part replacement analysis.
- Labor analysis of scaled-up operation.
- Failure analysis of field and accelerated corrosion test component failures.
- Spare part storage inspections.

5.3. Field Inspection Guideline Development and Data Acquisition.

5.3.1. Definition of Program. Development of program vehicles and field sites. The selection of vehicles to be studied was changed several times during the initial planning stages of this investigation. The problem was to find three different vehicles which were deployed in sufficiently large numbers which had major corrosion prevention measures applied during design and manufacture. The HMMWV, the CUCV, and the 5-Ton Truck were confirmed as program study vehicles.

The test sites originally planned were Europe, Korea, and Hawaii. Political problems in Korea forced this area to be replaced with a California site. The selection was as follows:

CONUS:	Fort Ord, California 7th Infantry Division
OCONUS-USAREUR:	New Ulm, West Germany 56th Field Artillery Bde

OCONUS-WESTCOM:	Schofield Barracks, Hawaii 25th Infantry Division

Permission was granted at each of these sites for the inspection program which resulted in the following schedule:

	Fort Ord	Schofield	Germany
Inspection 1	7-87	8-87	9-87
Inspection 2	1-88	2-88	5-88
Inspection 3	7-88	8-88	10-88

5.3.2 Field Inspection Guideline Development. Preparations were made to make inspections of 30 vehicles of each type at each location at six-month intervals. A prototype form was developed, printed and evaluated. A field test was conducted at Fort Knox, Kentucky 6,7 May 1987. Vehicle inspections were performed on each of the subject vehicles. Revisions were made to provide efficient inspection flow from front of vehicle, right side of vehicle, rear of vehicle, left side of vehicle and roof. Provisions were also established to monitor corrosion under hood, under body, exhaust system and interior. Inspection forms were then modified and printed in triplicate; white copy-1st inspection, yellow copy-2nd inspection, pink copy-3rd inspection.

5.3.3 Field Data Acquisition. Field inspections were carried out at each location using the inspection forms developed for the program. They are shown in Figures 5.3-1, 5.3-2, and 5.3-3. The only change not shown in the forms was made to expand the progression of rating corrosion levels from 4 to 5, in order to show a slight change in severity of attack over the 18-month duration of the study.

A total of approximately 855 individual inspections were performed during the program. Photographic documentation was made of each inspection, resulting in over 7,000 color prints. Each inspection form, with its associated photographs, was assembled into 27 loose leaf binders, one for each vehicle type, inspection, and area.

5.3.4. General Summary of Corrosion & Corrosion Maintenance Problems at the Unit Level. In addition to the inspection of the subject vehicles, the project team reviewed maintenance personnel at various organizational levels and observed, first

VEHICLE INSPECTION (EXTERNAL) DATE ____/____/____

VEHICLE TYPE: HUMMV VEHICLE I.D.: BUMPER # ____________ SERIAL # ____________

AGE: ________ MILEAGE: ________ USEAGE: ________ LOCATION: ________ INSPECTOR: ________

COMPONENT	TYPE CORROSION DAMAGE										CAUSE							REASON
	GR	GPB	GFI	GP	GW	LP	LG	LCR	LST	LW	D	Mt	A	Mn	R	E	Un	
I BODY & TRIM																		
Fr Bumper/Grill/Ties																		
Fr Lights																		
Hood/Handles/Bkts																		
R Fr Fender																		
R Fr Door/Bkts																		
R Rr Door																		
R Rocker/Step/Run Bd																		
R Rear Quarter Panel																		
Tailgate/Hinges																		
Rear Bumper																		
Rear Lights																		
L Rear Quarter Panel																		
L Rear Door																		
Cargo Bed																		
L Front Door/Bkts																		
L Rocker/Step/Run Bd																		
L Fr Fender																		
Roof																		
Mirrors/Brkt/Ant Mnt																		
Wheels/Hubs/Studs/Lugs																		
II UNDER HOOD																		
Right Inner Fender																		
Left Inner Fender																		
Fire Wall/Air Cleaner																		
Visible Frame																		
Radiator/Support																		
Bumper/Brkt																		
Hood Brackets/Mounts																		
Steering Column/Brks																		

TYPE OF CORROSION:

GR-General Rusting, GPB-General Paint Blistering, GFI-General Filiform Corrosion, GP-General Pitting, GW-General Wear
LP-Local Pitting, LG-Local Galvanic Corrosion, LCR-Local Crevice Corrosion, LST-Stress Corrosion, LW-Local Wear

RATING: 1 Initiation 2 Moderate 3 Advanced 4 Failed/Rust thru

CAUSE:
D-Design, Mt-Material, A-Accident/Physical, Mn-Lack of Maintenance, R-Poor/Improper Repair, E-Environmental, Un-Unknown

COMPONENT	TYPE CORROSION DAMAGE										CAUSE							REASON
	GR	GPB	GFI	GP	GW	LP	LG	LCR	LST	LW	D	Mt	A	Mn	R	E	Un	
III UNDER CARRIAGE																		
Front Axle																		
Front Suspension																		
Front Frame																		
R Fr Fender Well																		
R Fr Floor																		
R Rr Floor																		
R Rear Fender Well																		
Gas Tank																		
Rear Axle																		
Rear Suspension																		
Rear Frame																		
Cargo Bed																		
L Rear Fender Well																		
Left Rear Floor																		
L Fr Floor																		
L Fr Fender Well																		
Drive Shaft/U-Joints																		
Half Shafts																		
Other																		
IV EXHAUST SYSTEM																		
Manifold																		
Y-Pipe																		
Intermediate Pipe																		
Muffler																		
Tail Pipe/Shield																		
Clamps/Hangers																		
V INTERIOR																		
R Fr Door/Jams/Brkts.																		
R Fr Floor																		
R R Door/Jams/Brkts.																		
R R Floor																		
Cargo Area																		
L R Door/Jams/Brkts																		
L R Floor																		
L Door/Jams/Brkts.																		
L Fr Floor																		
Pedals/Steering Columns																		
Fire Wall																		
Radio Mount																		
Battery																		

Figure 5.3-1. HMMWV Inspection Form

VEHICLE INSPECTION (EXTERNAL) DATE ____/____

VEHICLE TYPE: CUCV VEHICLE I.D.: BUMPER # ____________ SERIAL # ____________

AGE ________ MILEAGE ________ USEAGE ________ LOCATION: ________ INSPECTOR ________

COMPONENT	TYPE CORROSION DAMAGE										CAUSE							REASON
	GR	GPB	GFI	GP	GW	LP	LG	LCR	LST	LW	D	Mt	A	Mn	R	E	Un	
I BODY & TRIM																		
Fr Bumper/Grill																		
Fr Lights																		
Hood																		
R Fr Fender																		
R Door																		
R Rocker/Cab																		
Rear Door/Panel/Hinges																		
R Rear Quarter Panel																		
Tailgate/Hinges/Lights																		
Rear Bumper																		
Rear Lights																		
L Rear Quarter Panel																		
L Door																		
L Rocker/Cab																		
L Fr Fender																		
Roof																		
Mirrors/Brkt/Ant Mnt																		
Wheels/Hubs/Studs/Lugs																		
II UNDER HOOD																		
Right Inner Fender																		
Left Inner Fender																		
Fire Wall																		
Visible Frame																		
Radiator/O F T																		
Battery/Tray																		
Hood Brackets																		
Steering Column																		

TYPE OF CORROSION

GR-General Rusting, GPB-General Paint Blistering, GFI-General Filiform Corrosion, GP-General Pitting, GW-General Wear
LP-Local Pitting, LG-Local Galvanic Corrosion, LCR-Local Crevice Corrosion, LST-Stress Corrosion, LW-Local Wear

RATING 1 Initiation 2 Moderate 3 Advanced 4 Failed/Rust thru

CAUSE
D-Design, Mt-Material, A-Accident/Physical, Mn-Lack of Maintenance, R-Poor/Improper Repair, E-Environmental, Un-Unknown

CCUV BUMPER # ____________

COMPONENT	TYPE CORROSION DAMAGE										CAUSE							REASON
	GR	GPB	GFI	GP	GW	LP	LG	LCR	LST	LW	D	Mt	A	Mn	R	E	Un	
III UNDER CARRIAGE																		
Front Axle																		
Front Suspension																		
Front Frame																		
R Fr Fender Well																		
R Fr Floor																		
R Rear Floor																		
R Rear Fender Well																		
Tank																		
Rear Axle																		
Rear Suspension																		
Rear Frame																		
L Rear Fender Well																		
L Fr Floor																		
L Fr Fender Well																		
Drive Shaft																		
Half Shafts/U Joints																		
IV EXHAUST SYSTEM																		
Manifold																		
Intermediate Pipes																		
Mufflers																		
Tail Pipes																		
Clamps/Hangers																		
Other																		
V INTERIOR																		
R Door/Jams/Brkts																		
R Fr Floor																		
Cargo Area/Rear Floor																		
Rear Door/Jams/Brkts																		
L Fr Floor																		
L Door/Jams/Brkts																		
Fire Wall																		
Other																		

Figure. 5.3-2 CUCV Inspection Form

VEHICLE INSPECTION (EXTERNAL) DATE ____/____/____

VEHICLE TYPE: 2½/5T VEHICLE I.D.: BUMPER # ______________ SERIAL # ______________

AGE: __________ MILEAGE: __________ USEAGE: __________ LOCATION: __________ INSPECTOR: __________

COMPONENT	TYPE CORROSION DAMAGE										CAUSE							REASON
	GR	GPB	GFI	GP	GW	LP	LG	LCR	LST	LW	D	Mt	A	Mn	R	E	Un	
I BODY & TRIM																		
Fr Bumper/Grill/Window																		
Hardware																		
Fr Lights/Trim																		
Hood/Brackets/Latch																		
R Fr Fender																		
Tool Box I																		
R Door																		
R Rocker Step/Run Bd																		
Tool Box II																		
R Rear Side Bed																		
Tail Gate/Hinges																		
Rear Bumper																		
Rear Lights																		
Cargo Bed																		
L Rear Side Bed																		
Fuel Tank																		
Door																		
L Rocker/Step/Run Bd																		
Air Cleaner																		
L Fr Fender																		
Roof/Cloth Cap Trim																		
Mirrors/Brkt. Ant Mnt																		
Wheels/Hubs/Studs/Lugs																		

TYPE OF CORROSION:

GR-General Rusting, GPB-General Paint Blistering, GFI-General Filiform Corrosion, GP-General Pitting, GW-General Wear, LP-Local Pitting, LG-Local Galvanic Corrosion, LCR-Local Crevice Corrosion, LST-Stress Corrosion, LW-Local Wear

RATING: 1 Initiation 2 Moderate 3 Advanced 4 Failed/Rust thru

CAUSE

D-Design, Mt-Material, A-Accident/Physical, Mn-Lack of Maintenance, R-Poor/Improper Repair, E-Environmental, Un-Unknown

2½/5T ______________

COMPONENT	TYPE CORROSION DAMAGE										CAUSE							REASON
	GR	GPB	GFI	GP	GW	LP	LG	LCR	LST	LW	D	Mt	A	Mn	R	E	Un	
II UNDER HOOD																		
Right Inner Fender																		
Left Inner Fender																		
Fire Wall																		
Visible Frame																		
Radiator Support																		
Hood Brackets/Mounts																		
Other																		
III UNDER CARRIAGE																		
Front Axle																		
Front Suspension																		
Front Frame																		
Front Floor																		
R Rear Fender Well																		
Rear Axle/Links																		
Rear Suspension																		
Rear Frame																		
Cargo Floor																		
L Fr Fender Well																		
Drive Shafts																		
Half Shafts																		
Other																		
IV EXHAUST SYSTEM																		
Manifold																		
Y Pipe																		
Exhaust Pipe																		
Muffler Shield																		
Clamps/Hangers																		
Tail Pipe																		
V INTERIOR																		
R Door Jams/Brkts																		
R Floor Seat Box																		
L Floor/Seat Frame																		
L Door Jams/Brkts																		
Pedals/Steering Column																		
Fire Wall																		
Battery Box																		
Seat Frames																		

Figure 5.3-3. 5-Ton Inspection Form

hand, corrosion-related repairs in progress. Storage of spare parts in the Army Supply System Inventories was inspected, as well as vehicles stored at depot facilities. Based on information obtained from these activities, the following general comments are offered:

The U.S. Army has for sometime made the prevention and control of corrosion within the tactical vehicle fleet an Army-wide priority. The Army logistics community has invested considerable effort and expense in an attempt to educate the field on the long-term effects of rust and corrosion, the "red peril," the "enemy from within." Unfortunately, at the unit or organizational level--i.e., company and battalion--this effort has resulted in limited success. The reasons are varied but are generally the result of the operational tempo within the unit, improper maintenance procedures, and a lack of adequate information and/or resources.

Clearly, the most significant problem in preventing corrosion at the unit level is the tempo at which these organizations operate. Unit-level commanders, maintenance personnel, and vehicle drivers are aware of the long term accumulative effects of rust and corrosion but function under and operational umbrella where day to day maintenance problems, such as lube, oil, filter, fueling, safety checks, etc., are more important than future concerns. There are tremendous pressures placed on these personnel to keep the equipment functioning for "today's mission." The concept of readiness is short term. Since corrosion is a time-dependent phenomenon, its deleterious effect on a vehicle's readiness normally occurs over several years and, therefore, does not receive high priority relative to immediate readiness. Corrosion-preventive measures are perceived as time consuming and without immediate reward. Therefore, unit level maintenance personnel tend to place rust prevention on the "back burner" or selectively do not comply with corrosion directives from higher headquarters, until such time that the corrosion of the vehicle becomes catastrophic, requiring extensive, time consuming, and costly repairs.

Maintenance of unit tactical vehicles is often subject to the priorities of the annual training schedule. Comprehensive maintenance, when corrosion prevention measures are normally addressed, is performed after major training events, such as ARTEPs, training center rotations, etc., and prior to the annual maintenance inspections. During these maintenance periods, a dedicated effort is made to eliminate most indications of general surface corrosion, since the observance of rust during an annual inspection is a general shorthand indication of unit maintenance standards. Often the treatment at that time is cosmetic, and the underlying causes of the corrosion attack are overlooked. Due to a lack of command emphasis and/or lack of proper material, manuals, time and equipment, corrosion repair procedures are performed which contribute to the long-term corrosion of a vehicle. For example, the vehicle surface is inadequately repaired, and unauthorized local purchase paint materials are applied over an affected area, completing a cosmetic repair but exacerbating the underlying problem that may result in more extensive and costly future repairs.

In addition to inadequate written corrosion prevention procedures, there are other Army-wide improper maintenance and care procedures that contribute to long-term corrosion problems. Tactical vehicle washing is often performed on combat vehicle wash racks using high pressure water hoses. High pressure does improve the speed at which heavy mud and salt deposits can be removed from external body parts. However, extreme pressure also forces water and corrosive deposits into vehicle seams and joints, which often leads to crevice corrosion and potential structural damage. Drivers of commercially purchased "off-the shelf" vehicles, such as the CUCV (Chevy Blazer) and Dodge Power Wagons, wash them as if they were true tactical vehicles capable of being washed inside and out. Water is entrapped under floor mats, between internal and external door panels, behind the dash and under seats, resulting in corrosion damage to floors, doors, locks, window regulators, and electrical instrumentation. Further, moisture observed in roof panels, cushions and floor pads lingers for long periods of time during which heating and cooling of closed vehicle interior support moisture condensation on interior components long after the vehicle has been washed.

Dedicated vehicle drivers would significantly enhance corrosion prevention, since these drivers normally take pride in the appearance and condition of their vehicles. They would take the time and effort to perform comprehensive maintenance, including corrosion prevention. Ingenious driver-initiated corrosion maintenance procedures were frequently observed. While this fact has been recognized by the Army for years, it is extremely difficult to implement a one vehicle-one driver program for any period of time at the unit/organizational level. Training, support requirements, personnel shortages, leave/PCS, promotions, relocations, and a variety of other demands make it impossible to have a vehicle driven and maintained by only the assigned driver.

Locally applied modifications to unit tactical vehicles contribute significantly to the corrosion problem. The mounting of radio antennas and convoy beacons is common throughout the Army and is all too frequently performed by vehicle drivers without proper instructions, materials, or supervision. These field expedient mounting procedures damage the limited rust proofing on the vehicle and dramatically increase the susceptibility to corrosion. Corrosion preventive procedures, such as galvanizing, undercoating, painting, should be performed after all fabrications and body panel holes have been made. Drilling mounting holes, or welding brackets after rust proofing, locally exposes unprotected metal surfaces, which ultimately leads to major body corrosion and costly repair.

Unit level maintenance records, especially vehicle log books, are not conducive to recording incidents of corrosion. In an attempt to reduce the amount of paperwork at the unit/organizational level, these records have been modified over a period of time to the point that they are limited in scope and temporary in nature. No permanent records are kept that accurately indicate whether of not a specific vehicle or an entire fleet has corrosion problems. Corrosion-related failures are not normally recorded as such and, therefore, no record is maintained for historical or statistical analysis. Accordingly, corrosion-related problems do not become apparent or achieve high visibility at the command level until they result in a vehicle dead-lining deficiency. Unfortunately, it is then too late to correct the problem without considerable expense.

While there continues to be emphasis on corrosion at higher headquarters, this emphasis has not cascaded down to the unit level in a manner that is pertinent to vehicle drivers, mechanics and unit commanders. Vehicle operator manuals are inadequate in defining the deleterious effects of corrosion and how to identify, prevent, and control corrosion for specific vehicles. As they relate to the prevention and control of corrosion, organizational maintenance manuals are also inadequate.

New technologies are not readily accepted at the unit level primarily because they have not been properly trained and indoctrinated to the use of the new materials or procedures. Chemical Agent Resistant Coating (CARC) is not well understood at the unit level and, in some cases, at the direct support level. Application of CARC paint is perceived as complicated, expensive, beyond unit level capability and, in some cases, contrary to OSHA, state or local environmental requirements. When CARC is applied at the unit level, it is frequently applied incorrectly or haphazardly. Spot painting of CARC vehicles is often performed with non-CARC paints locally procured by the driver--i.e., aerosol spray cans. There were even reported cases where CARC painted vehicles have been totally repainted with regular paint in preparation for maintenance inspections, parades, etc. Such instances occur even though technical directives warn of incompatibility when mixing CARC and non-CARC coating systems that may result in reduced levels of corrosion protection than either of the available paint systems used independently.

In order to reduce costs, units have elected or been directed to obtain cheaper POL products through the Army Supply System rather than expend unit funds for a higher quality product at the installation SSSC. Some of these products are marginally satisfactory and have had an impact on vehicle corrosion. For example, lower cost bearing grease was utilized at some sites. High temperatures, generated by heavy field use, resulted in breakdown of the lower-cost grease. Even with more frequent checking and regreasing (also not cost effective), there was a higher rate of wheel-bearing corrosion in those units that switched to the lower-quality grease.

Procurement of unspecified material is not spurred by cost alone. Availability and delivery time often influence unit-level procurement, particularly for nut and bolt hardware. Inferior grade bolts, hardware without protective plating (such as cadmium), or intermixing of materials with varied chemical/electrical potentials creating galvanic corrosion couplings were also frequently observed.

There are other corrosion problems for which the unit/organization has no control. Many of the new vehicles recently introduced into the field (HMMWV, CUCVM 939, etc.) have been in the "pipeline" for some time and have been stored or shipped without consideration of the impact of corrosion.

Many vehicles were observed at supply depots with significant corrosion problems. Consequently, many vehicles reach their final destinations in a corroded state. If delivery of the vehicle requires overseas shipment, the corrosion problems are significantly accelerated by sea-salt contamination. This is especially true for vehicle undercarriage components that are currently rust proofed and undercoated by the receiving organization.

Local undercoating and rustproofing performed on tactical vehicles varies from installation to installation. In some cases, this work is performed on the post by the direct general support maintenance facility. At other locations, the work is contracted to local firms specializing in corrosion prevention. In some cases, such products are not applied at all. Since the Army does not have a universal application standard for undercoating and rustproofing, local conditions prevail. While most work is performed in a satisfactory manner, the quality of materials varies, the method of application and quality of processing varies and very often is performed without the supervision of government quality control inspectors.

Regardless of what improvements are made in controlling corrosion, it will continue to pose a problem for the Army's Tactical Fleet. Not every problem can be technically and economically resolved over a short time interval. However, continued improvement in vehicle design, diligent maintenance, and frequent field inspections will help to control the corrosion problems to a manageable level.

5.4. Field Operations Manual (Requirements for Training Personnel)

5.4.1. Purpose. The purpose of this manual is to assist the user in the performance of "in-situ" field inspections for the occurrence and progression of corrosion observed on U.S. Army tactical vehicles.

The user will be familiarized with the inspection forms, TYPE corrosion, RATING (or degree) of corrosion, and general field inspection methods that will enable him to properly record the observance of corrosion damage to field vehicles. It is intended that the data collected during field inspections will be used to establish a computerized data base from which the following benefits may be derived:

- Early warning for Original Equipment Manufacturer (O.E.M.) design changes to subsequent vehicle acquisitions and/or replacement parts;

- Development of U.S. Army Supply System requirements;

- Early visibility for establishing improved maintenance procedures;

- Correlation of actual field data to any accelerated vehicle or component test results.

5.4.2 Inspection Forms. A sample of the modified inspection form is shown in Figure 5.4-1.

Frequent referral to this example is encouraged whenever the instruction manual is being used. This is an example inspection form and can be readily modified to meet the inspection requirements of any future vehicle configuration. The format of the form will not change. Therefore, instructions contained within this manual will be applicable throughout.

VEHICLE INSPECTION (EXTERNAL) DATE ____/____/____

VEHICLE TYPE: 2½/5T VEHICLE I.D.: BUMPER # ______________ SERIAL # ______________

AGE: ________ MILEAGE: ________ USEAGE: ________ LOCATION: ________ INSPECTOR: ________

COMPONENT	TYPE CORROSION DAMAGE										CAUSE					COMMENTS
	GR	GPB	GP	GW			LP	LCA	LCC	LW	Ac		Mn		Un	
I BODY & TRIM																
Fr Bumper/Grill/Window																
Hardware																
Fr Lights/Trim																
Hood/Brackets/Latch																
R Fr Fender																
Tool Box I																
R Door																
R Rocker/Step/Run Bd.																
Tool Box II																
R Rear Side Bed																
Tail Gate/Hinges																
Rear Bumper																
Rear Lights																
Cargo Bed																
L Rear Side Bed																
Fuel Tank																
L Door																
L Rocker/Step/Run Bd.																
Air Cleaner																
L Fr Fender																
Roof/Cloth Cap Trim																
Mirrors/Brkt/Ant Mnt																
Wheels/Hubs/Studs/Lugs																

TYPE OF CORROSION:

GR-General Rusting GPB-General Paint Blistering GP-General Pitting GW-General Wear

LP-Local Pitting LCA-Local Chemical Attack LCC-Local Crevice Corrosion LW-Local Wear

RATING: 1. Initiation 2. Minor 3. Moderate 4. Advanced 5. Failed/Rust thru

CAUSE: Ac-Accident/Physical, Mn-Lack of Maintenance, Un-Unknown

2½-5T ______________

COMPONENT	TYPE CORROSION DAMAGE										CAUSE					COMMENTS
	GR	GPB	GP	GW			LP	LCA	LCC	LW	Ac		Mn		Un	
II UNDER HOOD																
Right Inner Fender																
Left Inner Fender																
Fire Wall																
Visible Frame																
Radiator/Support																
Hood Brackets/Mounts																
Other																
III UNDER CARRIAGE																
Front Axle																
Front Suspension																
Front Frame																
Front Floor																
R Rear Fender Well																
Rear Axle/Links																
Rear Suspension																
Rear Frame																
Cargo Floor																
L Fr Fender Well																
Drive Shafts																
Half Shafts																
Other																
IV EXHAUST SYSTEM																
Manifold																
Y Pipe																
Exhaust Pipe																
Muffler/Shield																
Clamps/Hangers																
Tail Pipe																
V INTERIOR																
R Door/Jams/Brkts.																
R Floor/Seat Box																
L Floor/Seat Frame																
L Door/Jams/Brkts																
Pedals/Steering Column																
Fire Wall																
Battery Box																
Seat Frames																

Figure 5.4-1. Modified Inspection Form

Vehicle history must be accurately recorded, in order to assure inspection of the proper vehicle on subsequent inspection dates, as well as to assess the progressive nature of the corrosion processes that have been observed.

5.4.3 Vehicle History

- VEHICLE TYPE. Generally, the inspection form will be tailored to a specific vehicle, such as the HMMWV, CUCV, etc. In such a circumstance, no action by the inspector is required. However, when a common inspection form is offered for more than one vehicle (due to similarities of vehicle type), the inspector must select the proper vehicle type and designate this selection by circling the appropriate vehicle type. Example: (See Figure 5.4-2).

  - VEHICLE TYPE: 2 1/2/5T. Selection of the 5T (5-ton) Vehicle would be designated as follows:

  - VEHICLE TYPE: 2 1/2/5T

  - VEHICLE I.D.: BUMPER #
    The unit vehicle identification number referred to as "Bumper #" shall be recorded in this space. This number is generally found on the left-front bumper or right-rear bumper area of the vehicle.

- SERIAL #. The manufacturer's vehicle serial number (or registration number) shall be recorded in this space. This number is found on the manufacturer's identification plate located at the driver side door jamb or dash board locations (See Figure 5.4-2.). THIS NUMBER IS EXTREMELY IMPORTANT. As this identification number is unique to each vehicle, all computer data is cross-referenced to this number and, therefore, needs to be accurately recorded.

- DATE. The date on which the inspection has been conducted shall be recorded in the following manner:
  <u>month/day/year</u>
  example: 02/05/89 for February 5, 1989

  This information is important in determining the rate at which corrosion occurs between inspection intervals.

- AGE. Record the date of manufacture from the manufacturer's identification plate in the following manner:
  month/day/year
  example: 04/14/84 for April 14, 1984

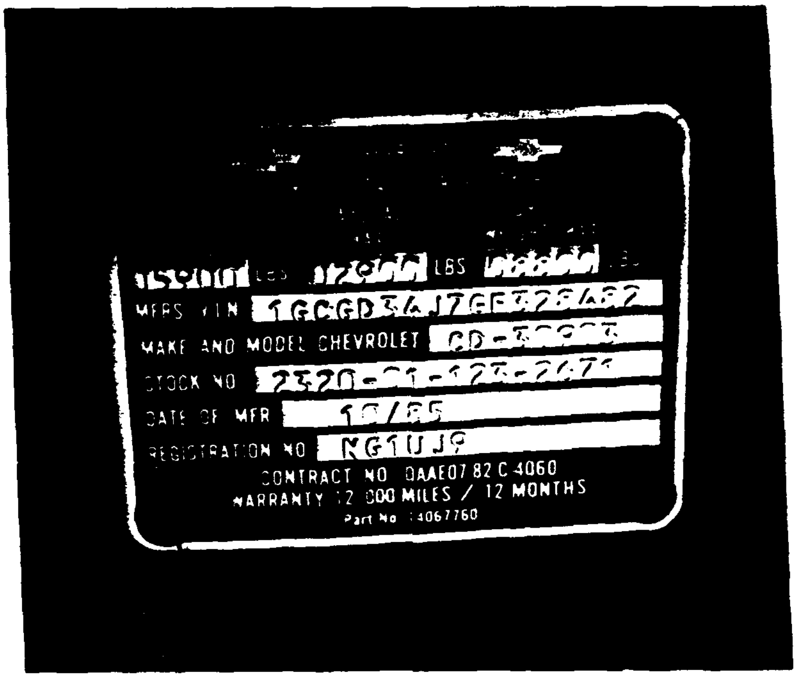


Figure 5.4-2. Manufacturers Inspection Plate

The computer program will automatically calculate the vehicle age at the time of inspection by making the following arithmetic computation:

Date of Inspection	02/05/89
Date of Manufacture	04/14/84
Age of Vehicle	4 years, 9 months, 21 days

- MILEAGE. Accurately record the vehicle mileage at the time of inspection from the vehicle odometer. Disregard tenths of miles.

  example: odometer reads: 001125.7
  inspector records: 1125

- USAGE. Usage refers to the model number of the vehicle as described by the appropriate TM manual. The model number usually refers to body style and/or functional use. For example, the CUCV is available as seven different models:

STOCK NO.	MODEL NO.
2320-01-123-6827	M1008
2320-01-123-2671	M1008A1
2320-01-123-2665	M1009
2310-01-123-2666	M1010
2320-01-127-5077	M1028
2320-01-158-0820	M1028A1
2320-01-133-5368	M1031

The manufacturer's identification plate will list the vehicle stock number. The inspector will record the appropriate vehicle model number (See Figure 5.4-2). Example:

I.D. Plate Lists: STOCK NO. - 2320-01-123-2671
Inspector Records: USAGE - M1008A1

- LOCATION. Location refers to the unit to which the vehicle is assigned, as well as the geographic site at which the vehicle is stored or maintained. Therefore, the unit and site location should both be recorded. Example:

RECORDING:	2-62ADA	Ft. Ord	is correct
RECORDING:	2-62ADA		is incomplete
RECORDING:	Ft. Ord		is incomplete

Remember, this information is important in determining the effects of environment on corrosion. In addition, this reference will be helpful in relocating a vehicle for subsequent corrosion inspections.

- INSPECTOR. The name or identification number of the individual performing the inspection shall be recorded. Changes in inspection personnel will alert the data collection coordinators to the need for training of new inspectors.

5.4.4. Description of Corrosion Damage. Corrosion damage of unprotected metal surfaces is readily observable, generally in the form of a change in surface color and/or texture, or in the formation of pits and/or deposits.

Many metal surfaces that will be inspected have, however, been protected from corrosive environments by the use of protective organic coatings such as paints and greases, or by metallic coatings such as plating and galvanizing. Quite often, the deterioration of these coatings is the first step in the ultimate corrosion of the underlying metallic component. Therefore, the following Corrosion Damage Categories have been included for data collection:

GR	General Rusting
GP	General Pitting
GPB	General Paint Blistering
GW	General Wear
LP	Local Pitting
LCA	Local Chemical Attack
LCC	Local Crevice Corrosion
LW	Local Wear

GB, GW, & LW - describe protective coating and paint deterioration. The severity level 1 through 5 is based upon surface area exposure of base metal. Therefore, when up to 1/5 of the surface area of the part has had the paint blistered, chipped, spalled, or worn, it is level 1, while 2/5 is level 2, etc.

GR, GP, LP, LCA, LCC, & LW - are the forms of rust. They are assumed to initiate on unprotected surfaces or after the protective coating has failed.

<u>Level 1.</u> <u>Initiation</u>:
Initiation of rust staining or local dulling minor discoloration of surface.

Level 2. Minor:
Red, black, gray, or white corrosion deposits on the surface accompanied by minor etching or pitting. No reduction of base metal cross-section.

Level 3. Moderate:
Powdered, granular, or scaled condition resulting in erosion of material from the surface. Minor cross-section reduction but, remaining base metal is sound and capable of supporting normal loads (still functional).

Level 4. Advanced:
Surface condition and corrosion deposits similar to Level 3, except there may be evidence of defoliation and spalling of corrosive product resulting in substantial cross-section reduction. Part structural integrity has been substantially reduced.

Level 5. Failed/Rust Through:
Cross-section has been penetrated and substantially weakened. Fluid retention is no longer possible. Part is susceptible to mechanical failure. No metal remains at the point of maximum corrosion.

5.4.5. Apparent Cause of Corrosion. Establishing the cause of vehicle component rusting and corrosion is not an easy task during field inspection. Many visual signs of corrosion cannot be readily diagnosed as to cause without extensive study.

The vehicle inspection form contains a section entitled "Cause and Comments." The inspector has three categories to select from:

- Ac - Accident/Physical; for example, an outside door panel has been dented, causing paint to be removed and initiating rust;

- Mn - Lack of Maintenance; for example, leaving a protective cover off an area, thus exposing it to corrosive attack;

- Un - Unknown, to indicate that the cause is not directly known to the inspector.

- Comments. This section is to be used to describe any special observations about the rusted part. Such comments could include:

- door panel smashed in accident;
- tie-down strap loose, causing paint to chip;
- oil pan dented.

These observations are helpful in isolating corrosion due to environmental conditions from those which are operator-generated.

5.4.6. Identification of Corroded Components. The importance of identifying the corroded part and its part number cannot be overstated. The data base that is being generated is dependent upon corrosion data properly assigned to part numbers.

As each area of the vehicle is examined, the parts observed are recorded by general description. The addition of part numbers on the form will aid the new inspector in identifying each component or assembly. It will also expedite data entry when form is completed.

5.4.7. Field Inspection.

- Frequency of Inspection: Field inspection data shall be recorded for each vehicle on an annual basis. It is strongly recommended that a consistent schedule of inspection be maintained for each vehicle.

  Example: Vehicle serial #123XYZ was initially inspected in July, 1987.
  Subsequent inspections should be conducted in July, 1988, 1989, 1990, etc.

- Inspection Routine: Develop a consistent inspection routine. Use this same routine for the inspection of all similar vehicles. This will ensure the completion of the task in an organized and repeatable manner. Such routines are advisable in sample data collection programs to ensure a consistent interpretation of data. The following general guidelines are recommended:

  - Establish a standard time to complete the inspection task for each type vehicle;

  - Use your inspection form to develop a consistent inspection pattern. Follow the order of general inspection groups. Example: The HMMWV inspection form lists general inspection groups as follows:

    I. Exterior Body & Trim
    II. Under Hood

III. Exhaust System
IV. Interior

- Inspect these groups in the following order. This same technique can be further broken down within these major categories:

  I. Exterior Body & Trim
  Proceed around the exterior portion of the vehicle in similar fashion for each vehicle inspected. Example:

  1. Front of vehicle (hood, grill, lights, etc.);
  2. Right side of vehicle (fender, door quarter panel, etc.);
  3. Rear of vehicle (bumper, lights, hitch, etc.);
  4. Left side of vehicle (quarter panel, door, fender, etc.);
  5. Top or roof of vehicle.

- Use this same order for each vehicle inspection. A similar technique should also be used for:

  II. Under Hood
  Proceed from left to right and develop a routine order of examining specific components.

  III. Undercarriage
  Proceed from front to rear and develop a routine order of examining specific components.

  IV. Exhaust
  Proceed from manifold to tailpipe and develop a routine order of examining specific components.

  V. Interior
  Proceed from driver door jamb to passenger door jamb. If applicable, check battery compartment and rear seat/internal storage areas.

- Keep informed of corrosion-related publications available to you through TACOM sample data collection personnel.

- Corrosion varies considerably with variations in the severity of environment. Consequently, another site inspector may report a particular form of corrosion or a specific part corroding in his environment before you have seen evidence of such attack on your inspection vehicles. Knowledge of such information will enable you to be alert to the earliest possible sign of similar corrosion.

- Be aware of corrosion maintenance and repair. If the vehicle you are inspecting has undergone any corrosion or maintenance repair, record the information in the Comment section for any component affected.

  Example: "Left front fender repainted since last inspection";

  "Muffler and tailpipe recently replaced";

  "New battery box installed since last inspection".

  Such comments will explain reversals in the degree of corrosion.

• Component: Component categories are presented in the following inspection order:

  I. Body and Trim
  These are essentially exterior portions of the vehicle.

  II. Under Hood
  These items are found in the engine compartment.

  III. Under Carriage
  Components on the underside of the vehicle.

  IV. Exhaust System
  Any and all exhaust components.

  V. Interior
  Components found in the driver/passenger side or inside storage areas.

• Items not inspected:

Keep in mind that the inspection procedure is an inspection of externally visible components only. Disassembly of major subassemblies for inspection of internal components or areas of the vehicle not visible, due to obstruction of the line of sight, are not required for inspection. For example:

Internal, engine, transmission, and rear components such as pistons, spark plugs, gears, etc., that would require disassembly for inspection are not required. External housings, brackets, or assemblies externally affixed to these components such as brackets, pulleys, pumps, etc., are required. External surfaces of doors and body panels require inspection. Inspection of the inside surfaces that require removal of interior door panels, etc., are not required.

- General:

  Listings of typical external components such as bumper, grill, lights, hood, doors, etc., are provided. Listing or any additional vehicle components may be recorded in the Comment section.

  The list of components should not be considered complete or fixed. After numerous inspections, it may be determined that certain components need to be added or deleted, depending upon the frequency or corrosion observations for that component. At that time, the component list may be modified or updated.

- Type of Corrosion Damage:

  The inspection form, when completed will be submitted for entry into data base computer for analysis.

5.5. <u>Computer Data Base Development and Instruction Manual</u>

5.5.1. Computer Data Base Development. After Field inspections at each site, over 90 inspection forms were assembled into loose leaf binders, dividing the data by inspection number, location and vehicle. The photographs were identified by part number and mounted next to the inspection that they pertain to. The part numbers for each component, found to show corrosion were then added to the inspection form.

This assembly of data was then ready for input to the computer. An IBM XT unit was used for initial data entry. This unit was found to be too slow and was replaced by an

Everex AT IBM compatible, which proved to be much faster and less time consuming.

The original contract called for the use of "Ashton Tate dbase III PLUS plus" software package. The computer consulting firm of Proassest, Newark, Delaware advised the use of Paradox 3.0 software for this type of data manipulation. Paradox was chosen because of its ease of programming, superior relational abilities, and faster operation. The Paradox data base also features built-in graphics. The change, approved by TACOM, was then implemented, and after several iterations, a workable data base system was developed and approved by TACOM.

5.5.2. Data Base Computer Instruction Manual

5.5.2.1. Introduction and List of Program Contents. This manual is comprised of actual computer display screens which have been transposed to a word processor. A computer display screen is 80 characters wide, and the printed page is approximately 65 characters.

The difference in widths causes some displays to appear somewhat different on the printed page, even though the content is the same.

Menu selections appear within a highlighted box cursor on the computer screen, this is signified with a '[' and a closing ']' bracket on the instructions.

Areas that represent actual screen displays are in bold print and appear darker then instructions that may be included with the screen.

In general, on-screen instructions will appear on the upper two lines of the computer display screen.

Menu screens will have a top line of selections with a second display line of explanation as to what the current highlighted selection will do. As you scroll the menu, the explanation line will change to match the current selection the cursor is highlighting.

Screens that information is entered on will be in a form type arrangement. Instructions on how to operate the form will appear on the top two lines of the screen.

On the forms, some fields will have tables which correlate the information you enter into the data field. As an example, if a vehicle serial number is entered, but a digit is mistyped, the computer will respond by highlighting the response and signaling with a warning message. Incorrect entries will not be accepted in these fields; however, the correct responses will be accessed by pressing function key 1. A table of correct responses will be displayed from which you can select the right answer.

Contents

- Installation
- Main Menu
- Inspection of Vehicles
- View Corrosion Data
- Cost Reporting
- Printing Reports
- Leaving the Program

5.5.2.2. Installation. The installation procedure is designed for installation on an IBM AT or compatible type computer.

The minimum hardware requirements are 640 kilobytes of memory, one 1.2 megabyte floppy drive, and a hard disk with a minimum of 15 megabytes of free disk space on designed drive 'C'.

Once it has been established that the hardware meets the requirements, check the config.sys file on the boot drive.

From the Dos prompt type: C:TYPE CONFIG.SYS

The resulting display should look similar to this:

```
Buffer=20
Files=18
```

Other devices may also be configured, but these are the two settings we need to check. Both Buffers and Files are required to be set to 20.

If the config.sys file requires adjustment, use any wordprocessor program that can edit Ascii files. The operating system editor may also be used.

To utilize the Dos editor enter: C:\EDLIN CONFIG.SYS

The Edlin prompt * will appear. Enter the letter L to list the file; line numbers will also be displayed.

```
* L <RETURN>
1. Buffers=20
2. Files=18
```

Now enter the line number that requires editing.

```
* 2 <RETURN>
```

2.*

Use the arrow keys to scroll from left to right, as you move the text for that line to appear. When you get to the equal sign, stop and enter 20 to replace 18; press return to complete the operation.

```
* 2
2.*Files=20 <RETURN>
```

Enter the letter E next to the prompt, to save the changes; type Q to quit, if you do not wish to save the editing.

Now that the hardware and system is right, reboot the system so the new config.sys will take effect.
Place the first Floppy disk in drive A: and make it the default drive by entering C:\ A:<RETURN>

At the A:\ prompt enter the word INSTALL; all directories and subdirectories will be created for you. The software files will then start to transfer to the hard disk; you will be prompted to change disks as required.

Enter TACOM at the C:\ prompt to start the program.

5.5.2.3. Main Menu Screen.

[Inspect] View Costs Add Vehicle Reports Storage Base Leave

Each selection will display a brief explanation on the second line of the screen when the cursor is highlighting that choice. Below is a summary of the explanations for each menu selection:

Choice	Explanation
Inspect:	Inspect Vehicle Parts for Corrosion
View :	View Inspected Vehicles Corrosion Records
Costs :	Report on Cost of Corrosion.
Add Veh:	Add New Vehicle to Inventory Record
Reports:	Print Reports on Corrosion of Vehicles
Storage:	Maintain a Log of Parts Storage
Base :	Base Standard Maintenance Supplies
Leave :	Leave the Application.

On Screen Instruction :

Use Arrow Keys <-- and --> to move highlighted cursor onto Menu choice for operation to perform. When selection is highlighted, press Enter to start performing the operation. Explanation of the highlighted operation will appear on second line of screen below Menu.

This screen will be the central point of the program's operation. It will be the opening menu and the place all routines will return to after completion.

When all operations are completed, the program will also be exited from this menu.

5.5.2.4. Inspection of Vehicles Menu Screen.

[Inspect] Main Menu Add Vehicle Edit Model Edit Cost
Inspect a Vehicle

Department of the Army
TACOM
Warren, Michigan

This is the main menu for the addition of vehicle inspection records to the data base.

A new vehicle can be added to the vehicle information table; a model's parts table can also be edited and its cost table adjusted.

Start by selecting the first menu choice "Inspect", move to an inspection and vehicle information form to be completed.

The top two lines display the operations which can be performed from this screen.

It requests that the form be filled out and that the [F2] function key be pressed to continue on to the corrosion inspection form.

Function key 10 will allow a past inspection to be recalled and additional corrosion information added.

Fill out Form, Press [F2] to continue to Corrosion Form.
[F8]=HardCopy

Press [F10] to view past inspection records, " Esc" to Cancel.

Department of the Army
TACOM
Warren, Michigan

Inspection Log In

Serial No. : Mileage :

Inspection No. : Inspection Unit :

Inspector : Date Inspected:

Reason Inspected

Note: Press [F1] for Look up Table on highlighted fields.Incorrect entry will not be accepted.

Continue on to the vehicle corrosion form; again, the top two lines display the selections. The cursor will appear in the Part # field; the inspection number and vehicle serial number will be filled in by the computer.

The correct part number may be found in any of several methods. Pressing [F1] will bring the parts table into view, the correct part can be selected with the [F2] key. Once selected the part number and ID will be placed into the form.

[F2] completes page and moves to Next Part Inspection or [F3] when done.[F5] forward 1 part,[F6] back 1, PgUp,PgDn,Home,
End reviews, [F9] Adds New Part.

```
---------------------------------------------
: Inspection # 3 Serial #              Part #          Part
I.D.  :
:           NG2E4N          MS-52150-31HE   CLAMPS/HANGERS:
:
------------------------------------------------------------
:  Remarks (25 chars max)
:                                     Type Corrosion Damage
:-----------------------
: [ 0  ] Cause Code                          General Corrosion
: 0.Unknown                              [ 2  ]  corrosion
: 1.Design                            [ 0  ]  paint blistering
: 2.Material             Rating Keys  [ 0  ]  filerform corr.
: 3.Accident/Physical     1.Initiation [ 2  ]  pitting
: 4.Lack of Maintenance   2.Minor       [ 0  ]  Wear
: 6.Poor/Improper Repair  3.Moderate
: 7.Environmental         4.Advanced      Local Corrosion
:                         5.Failed/      [ 0  ]  pitting
:                         Rust Thru    [ 0  ]  galvanic corr.
:                                       [ 0  ]  crevice corr.
:   Record #                            [ 0  ]  stress corr.
:        30                              [ 0  ]  wear
:
```

When [F1] is pressed, the parts table for this vehicle appears on screen with operating instructions. Placing the cursor in any field allows that field to be searched with Ctrl+Z.

When [F1] is pressed, a table appears on the screen with instructions on how to make a selection.

```
Move to the record you want to select.
Press [F2] to select the record; Esc to cancel; [F1] for help
PARTS-----Parts #------------Part------------Placement
     1 :  14072847  : MIRRORS/BRKT/ANT MNT  : 1. BODY & TRIM
  2 :  B&T        :  BODY & TRIM             :  1. BODY & TRIM
     3 :  14072422  :  BUMPER                 :  1. BODY & TRIM
```

Move the cursor to the Part # field and press Ctrl + Z to search for a specific value. The computer will prompt for a search value to be entered.

If the complete field is unknown, put in the value that is known and two periods. The ".." say search for this value and anything after it.

```
Value:  1407246..
Enter value or pattern to search for.
PARTS--Parts #----------------Part------------Placement
     1 :  14072847   :  MIRRORS/BRKT/ANT MNT :  1. BODY & TRIM
     2 :  B&T        :  BODY & TRIM          :  1. BODY & TRIM
     3 :  14072422   :  BUMPER               :  1. BODY & TRIM

   The search is now complete and 14072465 was found.

Move to the record you want to select.
Press [F2] to select the record; Esc to cancel; [F1] for help
PARTS--Parts #----------------Part-----------Placement
    38 :  14072465   :  RAIL ASSY./L.R.      :  1. BODY & TRIM
    39 :  14072466   :  RAIL ASSY./R.R.      :  1. BODY & TRIM
    40 :  14072467   :  RAIL ASSY./TAILGATE  :  1. BODY & TRIM
```

Placing the cursor on the value and pressing [F2] will automactically type the value in the Part # field, along with the Part ID.

Move on in the form by pressing Enter or the Tab key until the Remarks field appears. Twenty-five characters of descriptive text can be placed in this field.

It could be noted that a part was welded but not repainted, or the part was damaged in an accident but never repaired.

The next field will be Cause Codes. A list of acceptable responses will appear directly below the input field, along with an explanation of the code.

After hitting Enter from Cause Codes, the cursor will move to the first of the corrosion type fields. A key code of the Corrosion ratings is displayed to the left of the input fields; only values of this range will be accepted in the corrosion fields.

Once this form is complete, pressing the [F2] key will move to a new form. Again, the inspection number and vehicle serial number fields will be filled in by the computer. Also, whichever part is next in the parts table will be placed in the Part # and Part ID fields by the computer.

The [F5] and [F6] keys allow the parts table to be scrolled forward and backward from the form. Each time [F5] or [F6] are pressed, the values in the Part # and Part ID fields will change.

[F9] permits the addition of new parts to the vehicle's parts table from the program. If the part is not in the table, it will not be accepted when entered into the form.

When all Part's corrosion has been entered into the data base, pressing the [F3] key will complete data entry and return to the Inspection menu.

Inspect Main Menu [Add Vehicle] Edit Model Edit Cost
Add a new vehicle to inventory table

The Add Vehicle Menu selection is also available at the program's Main Menu. A vehicle must be entered into the Vehicle data base before it will be accepted as an input into Vehicle and Inspection information form.

When selected, the program will place you into a Vehicle information form which is to be completed.

The highlighted fields have Look-up Tables which can be accessed by pressing the [F1] key. Only these values will be accepted as input in these fields.

New data can be entered for these Look-up Tables by placing the cursor in the highlighted field and pressing [F10].

[F2] completes Vehicle additions, while [F3] moves to a new form to add more vehicles.

[F2] - Done; [F3] Add More Vehicles; Esc - Cancel; Ctrl-U - Undo last change, to add data to highlighted fields, place cursor on field and press [F10].

```
:                                : Department of the Army :
:                                :         TACOM          :
:                                 :    Warren, Michigan    :
:
:                                 Wheeled Vehicle Data Sheet
:                                  Type of Vehicle
:
:   Serial #
:   Location                              Unit :
:   Manufacturer                          Model #                    Year
:   Mileage
:
```

: Highlighted Fields have Look-Up Tables, Press [F1] for assistance.

Hitting Esc cancels the program and aborts all additions made this session.

The highlighted fields have Look-Up Tables which can be accessed by placing the cursor in the field and pressing [F1]. Since new vehicles are being added, new entries may need to be added for the Look-Up Tables. Only values that are verified as valid by the Look-Up Table will be accepted in highlighted fields.

It's very possible that some of the values for a new vehicle are not currently present in the Look-Up Tables. Place the cursor in the field that does not have the value required and press [F10]. The Look-Up Table will appear on screen in edit mode allowing the value required to be added.

Now that the value is present in the Look-Up Table, it will be accepted as a valid input for the field.

Inspect Main Menu Add Vehicle [Edit Model] Edit Cost
Edit the Parts table of a Vehicle Model.

This menu selection permits editing of a vehicle's parts table, but first the model number to edit must be indicated by moving the cursor onto the selection and pressing [F2].

Move cursor to selected model and press [F2].

```
MODEL---------Model#-------
     1 :  M-1008          :
     2 :  M-1009          :
     3 :  M-1025          :
     4 :  M-1028          :
     5 :  M-1038          :
     6 :  M-923           :
     7 :  [M-923WO]       :
     8 :  M-925           :
```

Once the model number is selected, its parts table is placed on the screen for editing.

Place Cursor on part to edit and press [F9]; [F2] when all parts are correct; [F3] to Abort edit; [F8] to Print Parts Table.

```
M-923WO--Parts#--------Part----------------------Placement-
 1 : 10883113  :  FR. BUMPER/PLATE          :  1. BODY & TRIM
```

2 :	12255890 :	GRILL	: 1. BODY & TRIM
3 :	[12256119 :	CAB ASSEMBLY	: 1. BODY & TRIM
4 :	12277058 :	WINDOW	: 1. BODY & TRIM
5 :	1227706 :	FR. BUMPER/GRILL/WINDOW	: 1. BODY & TRIM
6 :	12277061 :	WINDSHIELD\FRAME	: 1. BODY & TRIM

When [F9] for edit is pressed a change table appears which has the old part number and description already filled in. These fields are identified by OP# for old part number and OP for old part description.

If the new field is the same, place the cursor in the field and press [F3]. Press [F2] when this part is corrected. Return to the Parts table menu.

[F2] completes edit and goes to the corrosion table to change old inspection records to the new identification.

Abort edit and any changes made by pressing [F3].

Inspect Main Menu Add Vehicle Edit Model [Edit Cost]
Edit Parts Cost table

This allows the costs table to be edited for labor, part cost and number of hours to complete work.

Edit table, press [F2] when done, [F3] to Abort without saving.

PCOST	Part#	Part	Labor	PartCost
1 :	00009102 :	EME :	35 :	31 :
2 :	01215100 :	PARKING BRAKE :	35 :	46 :
3 :	102007zz :	STUDS/LUGS :	35 :	50 :
4 :	102007 :	WHEELS/STUDS :	35 :	23 :
5 :	1024585 :	REAR FRAME :	35 :	47 :
6 :	103706-05 :	FRONT AXLE :	35 :	45 :
7 :	1055650 :	SIDEMEMBER :	35 :	40 :
8 :	105603 :	WHEELS/HUBS :	35 :	32 :
9 :	1059-06601-01 :	STEERING VALVE :	35 :	20 :

Select Main Menu to return to the first menu.

Inspect [Main Menu] Add Vehicle Edit Model Edit Cost
Return to Main Menu

5.5.2.5. View Corrosion Data.

Inspect [View] Costs Reports Leave

View inspected vehicles corrosion records

The View choice allows access to the data base for viewing.

A series of questions will be asked to reduce the data to the specific items you wish to review.

First select the location to search.

[HAWAII] FTORD GERMANY
View Inspections in Hawaii

Now select one vehicle, or search the base for all vehicles.

[CUCV] HMMWV 5-TON All
View CUCV Inspections only

The computer will now take a few minutes to perform the query and locate all the data records. A table will be formed containing all the information about the vehicles selected.

Scrolling the table can be done with the Page up and Page down keys, the End key moves to the last record while the Home key returns you to the first. Place the cursor in any field and use Ctrl+Z to search for a specific value.

PgUp, PgDn, Arrow keys, End or Home keys to Scroll Table, Press [F2] when done

Place cursor on field, Ctrl + Z to search, Alt + Z finds next.

```
: RecNo --------------------  ----------------------------
:      1 Vehicle Information     Inspection Information
:
:    Location                  Inspection #             Cause
:    HAWAII                         1                     Code
:       Vehicle Type                         Mileage         :
:       CUCV                                 15616   0=Unknown
:       Model #             Inspection Unit           1=Design
:       M-1008                                      2=Material
:       Serial #                Date of Inspection  3=Accident
:       NG15DV                          8/18/87     4=NoUpkeep
:     Date of Delivery        Reason for Inspection 5=Bad Fix
:       3/01/84                                      6=Envrnmt
:
:     Part #           Description        Remarks         Cause
:     102007             STUDS/LUGS                           0
:        Gr    Gpb    Gfi   Gp    Gw    Lp    Lg    Lc    Lst   Lw
:       ----   ----   ----  ---   ---   ----  ---   ---   ----  ---
        3      3      0     0     0     0     0     0     0     0
:Rating:1=Initiation 2=Minor 3=Moderate 4=Advanced 5=Fail/Rust
```

```
Inspect  View  [Costs]  Reports  Base  Leave
Report on Cost of Corrosion.
```

This selection provides cost reports on specific vehicles. A summary report, which condenses the data into averages, or a detailed study that reports all information on the selected items, may be done.

```
Detail  [Summary]  Edit Cost  Exit
Produce a cost summary report
```

Select the vehicle to be reported.

```
[CUCV]  HMMWV  5 TON  Exit
Report on CUCVs
```

Select the vehicle's location.

```
[HAWAII]  FTORD  GERMANY  Exit
Report on CUCV in Hawaii
```

Select the kind of corrosion to be reported.

```
[Gr]  Gpb  Gfi  Gp  Gw  Lp  Lg  Lcr  Lst  Lw  Exit
Report on General Rusting
```

Example Report:

TACOM
Department of the Army

9/17/89 Page 1

Report on CUCVs in HAWAII

General Rust

Part #	Description	Labor	Part	Total
		COSTS		
105603	WHEELS/HUBS	35.00	32.00	

Average Age	Average Mileage	Part Count	Total Labor	Total Part	Total Cost
4.4	12848	1	35.00	32.00	0.00

5.5.2.6. Cost Reporting
Inspect View Costs [Reports] Leave
Print Reports on corrosion of vehicles

The first menu, after selecting reports, gives a choice of a detailed study of all data associated with the selected vehicle; "Summary" produces a condensed version of averages, while "Predict" will attempt to give a list of parts which have a high fail probability. "RParts" will report on a specfic part and give its history.

Detail Summary Predict RParts Esc
Report Corrosion with a summary report

Select the vehicle.

CUCV [HMMWV] 5 TON Exit
Report on HMMWV

Choose the location.

HAWAII [FTORD] GERMANY ALL Exit
Report on HMMWV in Ft.Ord

Select the type of corrosion to be reported.

[Gr] Gpb Gfi Gp Gw Lp Lg Lcr Lst Lw Exit
Report on General Rusting

Select a level of corrosion to start reporting from. You will be asked if you want just this level reported, or if this should be the starting point, and all levels greater then this will be included.

1 2 [3] 4 5
Level 3, Moderate Corrosion

Report on only this level, or this level and any corrosion at a higher Level?

Respond O=Only this level; H=this level and higher; O/H

Example report:

TACOM
Department of the Army
9/17/89 Report on HMMWVs in FTORD
Page

Part #	Description	Number of Incidents	Ave. Age	Mileage	Corrosion Level
5574585	ROOF/TOP CARGO				
Inspection#					
		1	1	1.5	4
		2	1	2.0	4
		3	1	2.5	4

5.5.2.7. Printing Reports

Inspect View Costs [Reports] Leave
Print Reports on corrosion of vehicles

The first menu, after selecting reports, gives a choice of a detailed study of all data associated with the slected vehicle; "Summary" produces a condensed version of averages while predict will attempt to give a list of parts which have high fail probability. "RParts" will report on a specific part and give its history.

Detail Summary Predict RParts Esc
Report Corrosion with a summary report

Select the vehicle.

CUCV [HMMWV] 5 TON Exit
Report on HMMWVs

Choose the location.

HAWAII [FTORT] GERMANY ALL Exit
Report on HMMWV in Ft.Ord

Select the type of corrosion to be reported.

[Gr] Gpb Gfi Gp Gw Lp Lg Lcr Lst Lw Exit
Report on General Rusting

Select a level of corrosion to start reporting from. You will be asked if you want just this level reported, or if this should be the starting point and all levels greater than this will be included.

1 2 [3] 4 5
Level 3, Moderate corrosion

Report on only this level or this level and any corrosion at a higher level?

Respond o=only this level, H+ this level and higher, O/H

Example report:

		TACOM		
		Department of the Army		
9/17/89		Report on HMMWVs in FTORD		
Page				
Part #	Description	Number of	Average	Corrosion
5574585	Roof/top Cargo	Incidents	Age	Level
Inspection #				
		1	1.5	4
		1	2.0	4
		1	2.5	4

Detail Summary [Predict] RParts Esc
Predict Parts to fail

Select "Predict" to get tables of failed and anticipated failures.

CUCV HMMVW 5 TON Exit
Report on HmmWvs

The HMMWV vehicle type was selected for the example.

[HAWAII} FTORD GERMANY ALL Exit
Report on HMMWVs in Hawaii
Hawaii has been choosen as the location. Now a table of the vehicle's models will appear.

ANSWER--------	Model--------
1	M-1025
2	M-1038
3	M-966
4	M-966
5	[M-998]

M-988 was the choice taken for the demonstration. Two tables will result from the query performed on the menu selections.

One table is all parts that have obtained a level rating of 4 as of the most recent inspection. This is advanced corrosion and the part is near a fail level.

The other table will be parts at level 5 or failed but not yet replaced or repaired as of the most recent inspection.

Both tables can have summary reports produced and detail reports which list the vehicles serial number for location of the damaged part.

Detail Summary Predict [RParts] Esc
Report on Selected parts

RParts allows a selected parrt to be reported on for the choosen vehicle type and model number.

TMODEL	Type	Model#
5Ton	5 Ton	M-923
2	5 Ton	M-923WO
3	CUCV	M-1008
4	HMMWV	[M-998]

Hmmwvs model number m-998 was selected

M-998	Part#	Part	Placement
1	[186676]	R.FR. FLOOR/BOLT	3.UNDER CARRIAGE
2	5579687	R.SUSP/CROSS MEMBER	3.UNDER CARRIAGE
3	5578822	R.SUSP/ARM CON&BALL	3.UNDER CARRIAGE

Part number 186676 was selected to be reported on.

Example Report:

TACOM
Department of the Army
Vehicle Corrosion Report

Germany

Vehicle Type: HMMWV
Model : M-1025 Part # 186676

Serial #	Year											
014917NG21ZE	August 1, 1986		GR	Gpb	Gfi	Gp	Gw	Lp	Lcr	Lst	Lw
Inspection #	Age	Mileage									
1	1.1	886	0	0	0	0	0	0	0	0	0
2	1.8	3,218	0	0	0	0	0	0	0	0	0

5.5.2.8 Leave the Program
Inspect View Costs Reports [Leave]
leave the application

this selection exits the program and returns to the main directory.

5.6 Failed Part Replacement Analysis

Data collected and entered into the corrosion data bank was processed so that vehicle part numbers showing corrosion could be flagged and monitored for either existing or future failure. This anticipated failure was to be compared to the manufacturer's anticipated service life of the part. The subject vehicle manufacturers were contacted and either would not, or could not, give the team an anticipated life of designed mileage for this equipment.

For the purpose of computer data analysis, the following criteria were used:

- Anticipated service life — 15 yrs
- Anticipated mileage life — 100,000 miles
- Level 4 corrosion-advanced state of corrosion and a high risk of failure
- Level 5 corrosion-considered failed but still in service as of last inspection

These values are used to establish a predicted life cycle for an individual part represented as a part number.

For example: a HMMWV has a Headlight assembly, Part # 5591170, which has level 4 corrosion, 2.5 years in service with 5,280 miles recorded.

$$\frac{2.5 \text{ years}}{15 \text{ years}} = 17\% \text{ of expected service life}$$

$$\frac{5{,}280 \text{ miles}}{100{,}000} = 5\% \text{ of expected mileage life}$$

To run the prediction program, select reports from the main menu. A submenu will appear which has "predict" as a selection. Like running the other reports, you will be prompted with menus to select location, vehicle type, and model number. The program then produces two tables. One table of advanced corrosion, rated at level 4, and one of failed parts, rated at level 5.

The tables will both be available for viewing or reporting. A function key will toggle from one table to another.

Examples from each of these tables are shown in Tables 5.6-1 and 5.6-2. They are based on dimulated data, in that corrosion level numbers were artificially produced so that reports could be generated. The actual data base of over 20,000 entries has very few level 4 and 5 corrosion examples.

Table 5.6-1. Level 4 Advanced Corrosion

Vehicle: HUMMV
Location: Hawaii

TACOM
Department of the Army
Vehicle Corrosion
Advanced Summary

Part	Name	Inspection	Averages Age	Averages Mileage	Incident Count	%ofPredict Age	%ofPredict Miles	Gr	Gpb	Gfi	Gp	Gw	Lp	Lg	Lcr	Lst	Lw
Part 00009102	BRKTS	Inspection # 3	2.5	1,683	4	17%	2%	4	0	0	0	0	0	0	0	0	0
Part 120520	FIRE WALL	Inspection # 3	2.4	1,623	1	16%	2%	4	0	0	0	0	0	4	0	0	0
Part 156455	WINDOW FRAME	Inspection # 3	2.4	1,623	1	16%	2%	4	0	0	0	0	0	0	0	0	0
Part 186676	R. FR. FLOOR	Inspection # 3	2.4	1,730	3	16%	2%	0	0	0	0	0	0	4	0	0	0
Part 18NA	FRONT AXLE	Inspection # 3	2.4	1,485	1	16%	1%	1	0	0	0	0	0	0	4	0	0
Part 19711-N	INTERMEDIATE PI	Inspection # 3	2.7	1,566	3	18%	2%	4	0	0	0	0	0	0	0	0	0
Part 19711-N-IP	INTERMEDIATE PI	Inspection # 3	2.5	1,771	4	17%	2%	4	0	0	0	0	0	0	0	0	0
Part 19711-N-M	MUFFLER	Inspection # 3	2.5	1,595	3	17%	2%	4	0	0	0	0	0	0	0	0	0
Part 2-5-6880	DRIVE SHAFT	Inspection # 3	2.5	1,396	1	17%	1%	4	0	0	0	0	0	0	0	0	0
Part 2-60-966	DRIVE SHAFT/FRO	Inspection # 3	2.5	1,717	4	17%	2%	4	0	0	0	0	0	0	0	0	0
Part 2436161	R. FR. FLOOR/WA	Inspection # 3	2.4	1,730	3	16%	2%	0	0	0	0	0	0	4	0	0	0
Part 27NA	DRIVE SHAFT	Inspection # 3	2.5	1,236	5	17%	1%	4	0	0	0	0	0	0	0	0	0
Part 28NA	DRIVE/HALF SHAF	Inspection # 3	2.6	1,472	8	17%	1%	4	0	0	1	0	1	0	0	0	0

Vehicle: HUMMV
Location: Hawaii

TACOM
Department of the Army
Vehicle Corrosion
Advanced Detail

NG23B2 Inspection# 3

Part	Name	Age	Mileage	%ofPredict Age	%ofPredict Miles	Gr	Gpb	Gfi	Gp	Gw	Lp	Lg	Lcr	Lst	Lw
Part 28NA	DRIVE/HALF SHAF	3.1	2,033	20%	2%	4	0	0	0	0	1	0	0	0	0
Part 39-NA	RADIO MOUNT	3.1	2,033	20%	2%	1	4	0	0	0	0	0	0	0	0
Part 5534414	CLAMPS	3.1	2,033	20%	2%	4	0	0	0	0	0	0	0	0	0
Part 5573014	FRONT SUSPENSIO	3.1	2,033	20%	2%	4	0	0	4	0	0	0	0	0	0
Part 5574962	MANIFOLD(LEFT)	3.1	2,033	20%	2%	4	0	0	0	0	0	0	0	0	0
Part 5579471	REAR SUSPENSION	3.1	2,033	20%	2%	4	0	0	4	0	0	0	0	0	0
Part 5581401-L	L. FRT DOOR	3.1	2,033	20%	2%	4	4	0	0	0	0	0	0	0	0
Part 5582364	MANIFOLD(RIGHT)	3.1	2,033	20%	2%	4	0	0	0	0	0	0	0	0	0
Part 5582603	Y-PIPE	3.1	2,033	20%	2%	4	0	0	0	0	0	0	0	0	0

Table 5.6-2. Level 5 Failure Corrosion

Vehicle: HUMMV
Location: Hawaii

TACOM
Department of the Army
Vehicle Corrosion
Failure Summary

Averages Age	Mileage	Incident Count	%ofPredict Age	Miles	Gr	Gpb	Gfi	Gp	Gw	Lp	Lg	Lcr	Lst	Lw
Part 4NA		R. REAR QUARTER			Inspection # 3									
2.5	1,313	1	17%	1%	0	0	0	0	0	0	0	0	0	0
Part 5578415		HOOD BRACKETS			Inspection # 3									
2.4	841	1	16%	1%	1	5	0	0	0	0	0	0	0	0
Part 5578749		BUMPER/GRILL			Inspection # 3									
2.6	1,766	1	18%	2%	5	0	0	0	0	0	0	0	0	0
Part 5579065		RADIATOR HOSE			Inspection # 3									
2.6	1,531	4	17%	2%	5	0	0	0	0	0	0	0	0	0
Part 5579675		FENDER PLATE			Inspection # 3									
2.4	2,165	1	16%	2%	5	4	0	0	0	0	0	0	0	0
Part 5581401-R		R. FR. DOOR BKT			Inspection # 3									
3.1	2,033	1	20%	2%	5	4	0	0	0	0	0	0	0	0
Part 5583349		TRANS/OIL COOLE			Inspection # 3									
2.7	1,832	3	18%	2%	5	0	0	0	0	0	0	0	0	0
Part 558349		TRANS/OIL COOLE			Inspection # 3									
2.4	2,300	1	16%	2%	5	0	0	0	0	0	0	0	0	0
Part 5586150		MIRRORS/ARM			Inspection # 3									
2.5	1,396	1	17%	1%	5	0	0	0	0	0	0	0	0	0
Part 5588176		HOOD/BKTS			Inspection # 3									
2.6	1,657	6	17%	2%	5	5	0	0	0	0	0	0	0	0
Part 5588179		HOOD/BKTS			Inspection # 3									
2.7	1,651	2	18%	2%	5	5	0	0	0	0	0	0	0	0
Part 8741461		FR. LIGHTS/BACK			Inspection # 3									
2.4	1,268	1	16%	1%	5	0	0	0	0	0	0	0	0	0
Part COV-0909		CLAMP			Inspection # 3									
2.9	1,900	2	19%	2%	5	0	0	0	0	0	0	0	0	0

Vehicle: HUMMV
Location: Hawaii

TACOM
Department of the Army
Vehicle Corrosion
Failure Detail

NG23B2 Inspection# 3

Part	Description	Age	Mileage	%ofPredict Age	Miles	Gr	Gpb	Gfi	Gp	Gw	Lp	Lg	Lcr	Lst	Lw
Part 5579065	RADIATOR HOSE	3.1	2,033	20%	2%	5	0	0	0	0	0	0	0	0	0
Part 5581401-R	R. FR. DOOR BKT	3.1	2,033	20%	2%	5	4	0	0	0	0	0	0	0	0
Part 5583349	TRANS/OIL COOLE	3.1	2,033	20%	2%	5	0	0	0	0	0	0	0	0	0
Part 5588176	HOOD/BKTS	3.1	2,033	20%	2%	5	5	0	0	0	0	0	0	0	0
Part 5588179	HOOD/BKTS	3.1	2,033	20%	2%	5	5	0	0	0	0	0	0	0	0
Part COV-0909	CLAMP	3.1	2,033	20%	2%	5	0	0	0	0	0	0	0	0	0

NG24AY Inspection# 3

Part	Description	Age	Mileage	%ofPredict Age	Miles	Gr	Gpb	Gfi	Gp	Gw	Lp	Lg	Lcr	Lst	Lw
Part 5578749	BUMPER/GRILL	2.6	1,766	18%	2%	5	0	0	0	0	0	0	0	0	0

5.7 <u>Labor Projections for Scaled Up System.</u>

5.7.1. Present System Costs. The data base system developed for this program involves totally manual data collection and computer loading. The following is a listing of labor costs which represent the inspection performed for this report and is based on examining 30 HMMWV's at one location by a single inspector.

Locate and identify vehicles	2 hrs
Corrosion inspection	15 hrs
Assemble inspection forms	1 hr
Add part numbers to inspection forms (average: 21 min./inspection set x 30 sets)	10.5 hrs
Enter inspection data into the computer program (average: 11.6 min/inspection set x 30 sets) hrs	58
Total	34.3 hrs

(1.14 hours or 68.6 minutes /vehicle inspection)

5.7.2. Projected System Costs. A proposed data collection system addresses all the areas of the present system and reduces or eliminates the manual-labor intensive areas. The system is based on a "hand-held data collection unit" which would function as follows:

- Vehicle data, S/N, model, mileage, etc., would be entered directly into HDCU.
- Computer screen would display vehicle to be inspected with visual breakdown of physical areas, parts and part numbers.
- Corrosion type, rating, and cause would be entered directly with wand to part number, displayed on the touch sensitive screen.
- Disk is then sent from the field inspection site to be added to the data base.

The anticipated labor costs for the inspection detailed in 5.7.1, would be as follows:

Locate and identify vehicles	2 hrs
Corrosion inspection average (20 min/vehicle)	10 hrs
Upload data for storage	5 hrs
	12.5 hrs

(.42 hrs or 25 min /vehicle inspection)

Use of the HDCU would reduce the cost of data collection and processing by approximately 1/3 and improve reporting accuracy as well.

5.8. Analysis of Field and Accelerated Corrosion Test Component Failures

5.8.1. Task Outline. This part of the project involved the collection and analysis of failed vehicle components to determine why the failure took place, with special emphasis on rust and corrosion.

The subject vehicles for this investigation included the High Mobility Multipurpose Wheeled Vehicle (HMMWV), the Commercial Utility Cargo Vehicle (CUCV), and the 939 series of the 5-Ton truck. These vehicles were selected based on availability from a logistics viewpoint and from a technical viewpoint, on the basis of corrosion preventive design improvements that were included in the original manufacture of these vehicles (The impact of these corrosion and preventive design improvements could be evaluated).

Information supplied by TACOM vehicle program management indicated limited exposure to the corrosive field environments based on the age of the subject vehicles.

Fielding of the HMMWV commenced in October of 1985 and has resulted in the deployment of approximately 23,000 vehicles as of September 1988. For the purpose of our investigations, an average vehicle age of two years was assumed.

Fielding of the CUCV commenced in September 1983, and has resulted in a field population of approximately 61,000 vehicles as of September 1988. An average vehicle age of four years has been assumed.

Deployment of the 939 5-Ton commenced in October of 1983 and has resulted in the fielding of approximately 16,000 vehicles as of September 1988. An average vehicle age of four years has been assumed for the 5-Ton vehicle.

As corrosion is a time- dependent phenomenon which, in many cases, requires a gestation period for protective coating failure prior to base metal attack, or prolonged exposures before a part is deemed unsuitable for continued use, it is not surprising that there have been relatively few failures totally attributed to corrosion. In addition, the attention paid to corrosion prevention in the design and procurement stages of fielding the subject vehicles, such as the use of: (1) dual-sided hot dip galvanizing treatments of body components (CUCV); (2) composite materials, such as Kevlar and fiber glass (HMMWV); (3) O.E.M. application of rust proofing and undercoat materials (939 5-Ton); and (4) application of CARC paint (all vehicles) further retarded the progression of the corrosive failure processes.

5.8.2. Failed Component Acquisition. For the period commencing in May 1988 and ending in September 1988, the ASC project team, with the assistance of PECO Enterprise field representatives, was successful in obtaining 248 components that were removed from the U.S. Army Supply System, and returned for laboratory analysis. All parts were removed from the subject vehicles per the following site schedule:

SYSTEM	SITE	# of Components
CUCV	Ft. Lewis	7
	Ft. Ord	5
	Ft. Polk	21
	Ft. Stewart	20
	Schofield Barracks	43
TOTAL		96
HMMWV	Ft. Lewis	22
	Ft. Ord	31
	Neu Ulm	20
TOTAL		78
M939	Ft. Polk	17
	Ft. Stewart	26
	Schofield Barracks	31
		74

TOTAL NUMBER OF FIELD VEHICLE COMPONENTS 248

In addition, failed components from the accelerated corrosion test run by AM General on the HMMWV at Transportation Research Center, of Ohio, were made available for analysis.

SYSTEM	SITE	# of COMPONENTS
HMMWV	TRC Test Grounds	42

TOTAL OF PARTS ANALYZED 290

5.8.3. Failure Analysis Guidelines and Procedure. Each component was analyzed systematically, following the general guidelines and procedure set forth by the American Society for Metals, Metals Handbook, Ninth Edition, Volume II, Failure Analysis and Prevention: 1986.

Individual results were reported as "Case Histories" with the following information:

- Record vehicle and part data;
- Document laboratory observations;
- Summarize appropriate corrosion preventive actions;
- Present comments and recommendations.

In the course of evaluating each case history, the following overall guideline was used:

> "The analysis would continue to proceed with additional stages and depth of investigation until such point that the cause of failure was determined or that corrosion as a necessary or sufficient condition for failure could be ruled out. That is to say, if no evidence of corrosion contributing to the cause of failure could be identified, the nature of an electrical or a mechanical failure would not necessarily be pursued. As this was a corrosion investigation, confirmation that corrosion was not involved in the failure was considered sufficient information, and investigation of the cause of failure was discontinued."

The stages of detailed analysis:

- Collect background data
- Preform a preliminary examination of the failed part.
- Examine the surface under low- power magnification of 10 to 60x.
- Brush or scrape off some of the corrosion products for qualititive or quantitative analysis.
- Identify areas of pitting, cracks, crack initiations, wear, erosion, fretting, parting peculiar to the various types of corrosion. These areas may be documented by a sketch or photograph.

- Obtain physical, mechanical and chemical composition data of failed part.
- Identify any defects in the material.
- Examine fractures by standard fractographic techniques.
- Cut a section from the part for metallographic examination.
- Examine for cracks, crack propagation, microstructure, grain boundary attack, second phases, porosity, oxides, and other inclusions to further establish cause of failure. Photomicrographs will be taken to document the problem.
- If necessary, quantify the foregoing results with the scanning electron microscope, energy dispersive x-ray analysis and/or electron microscope studies.

5.8.4. Discussion of Field Failure Case Histories.
A representative case history of a failed component examined during this program is shown in Figure 5.8-1. Of the 248 field- supplied components studied during this investigation, approximately by 11 percent were determined to have been removed from service due to corrosion related difficulties. An additional 20 percent of the parts showed various forms or corrosion that were not directly related to the cause of failure. The breakdown of data for the analysis is as follows:

CAUSE OF FAILURE

# of Parts		Corrosion	Mechanical	Electrical	Unknown
CUCV	96	4-4.2%	54-56.3%	10-10.4%	28-29.1%
HMMWV	78	5-6.4%	43-55.2%	17-21.8%	13-16.6%
5-Ton	74	18-24.3%	34-45.9%	7-9.5%	15-20.3%
Total	248	27-10.9%	131-52.8%	34-13.7%	56-22.6%

The 5-ton 939 truck showed the largest incidence (24.3 percent) of failure due to corrosion with the CUCV showing the least (4.2 percent).

It should be noted that although many of the components analysed were not confirmed corrosion failures, the

CASE HISTORY NO. 39

VEHICLE DATA

Vehicle Type: HMMWV   Vehicle Serial No.: 594

Location of Vehicle: Fort Ord

Mileage on Vehicle: 8,750   Age of Vehicle: ≈2 yrs.

PART DATA

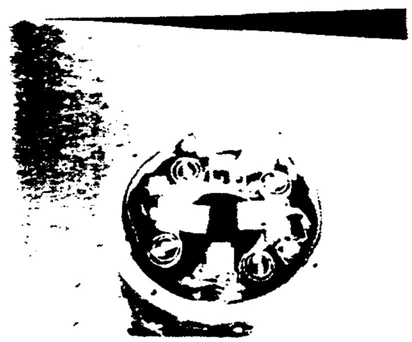
Part Serial No.: MFY2101SS   Part Description: Starter Motor

Definition of Case History:

Failure of starter motor

Observations:

- Minor external corrosion of mounting bolt
- Severe internal corrosion of housing, field, and brush plate
- White deposits on zinc plated surfaces
- Red-brown deposits on steel surfaces
- Deposits contain very high concentration of chlorides



Corrective Actions:

The high concentrations of chlorides indicate that the starter motor assembly may have been submerged in salt water. When fording salt water, it may be necessary to clean properly components that cannot be adequately sealed due to mechanical function.

Comments/Recommendations:

Develop special maintenance procedures to be utilized after deep water fording in brackish or salt water environments.

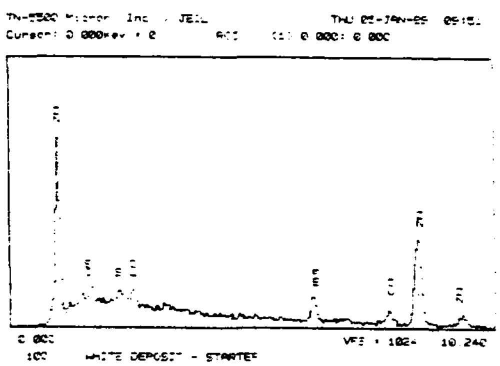


Figure 5.8-1. Field Failure Case History

accumulation of such information is useful in assessing the success of the corrosion prevention design modifications that were utilized for these vehicles. This data represents the first attempt to quantitify the magnitude of the corrosion failure rate, as no previous distinction between mechanical, electrical, or corrosion failure mechanisms had been accurately determined or documented.

A list of the parts analysed for this program is included in appendices A B & C. The 248 complete case histories were submitted to TACOM as separate reference volumes.

5.8.5. Discussion of Accelerated Corrosion Test, Failed Component Case Histories

This group of 42 components were obtained from AM General Company at the completion of an accelerated corrosion test run on two HMMWV units at Transportation Research Center (TRC). Corrosion was the predominant cause for retirement from service. Parts removed prior to completion of the 300-cycle test are considered component failures. Any parts that completed the full 300 cycles were evaluated from a corrosion viewpoint and related to a projected cause of failure.

Individual case histories were reported using the same format as the field failures (section 5.8.4). A list of these studies is included in appendix D. The completed 42 reports were submitted to TACOM as a seperate reference volume.

When possible, the TRC data was related to data from identical parts from field failures or field inspection results (i.e., corrosion type & level), with regard to life expectancy. This correlation was made in order to test the accuracy of the TRC cycle/life correlation of 20 cycles being equivalent to one year of field operation.

An example of a typical case history is shown in Figure 5.8-2.

CASE HISTORY NO. T9

VEHICLE DATA

Vehicle Type: HMMWV   Vehicle Serial No.: NG2G6D

Location of Vehicle: TRC

Mileage on Vehicle: 11121   Age of Vehicle: 222 cycles
11 years

PART DATA

Part Serial No.: 5588022   Part Description: Oil Pan

Definition of Case History:

Rust through of engine oil pan

Observations:

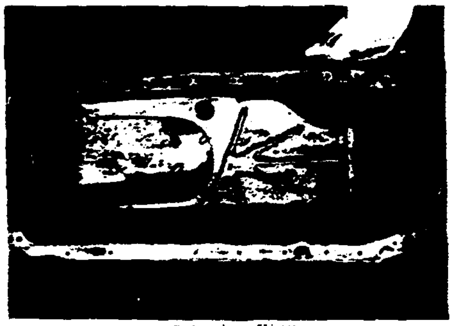
- Extensive failure of external paint protection
- Heavy general corrosion attack to the point of penetration
- Minor general surface corrosion of inside surfaces. (After the part was cleaned and degreased)
- Wall was penetrated in deepest part of oil well resulting in loss of engine oil

Corrective Actions:

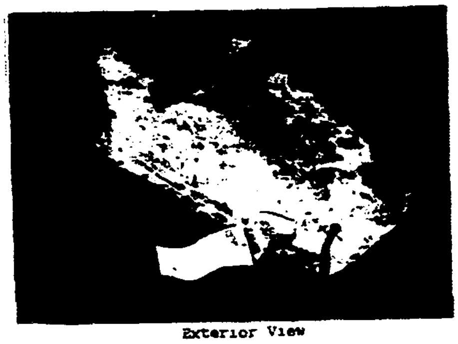
External surfaces should be protected with a plating material. Hot dip galvanizing is recommended.

Comments/Recommendations:

Inspection of two year old field vehicles demonstrated early signs of paint chips, spalling and areas of general corrosion attack. Continued inspection and maintainence of oil pan external surfaces will extend life. This part may fail premature of TRC projections.

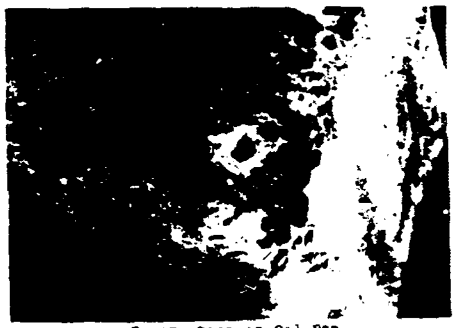


Interior View



Exterior View

Section Adjacent to Penetration Showing Corrosion of Exterior Surface



Penetration in Oil Pan

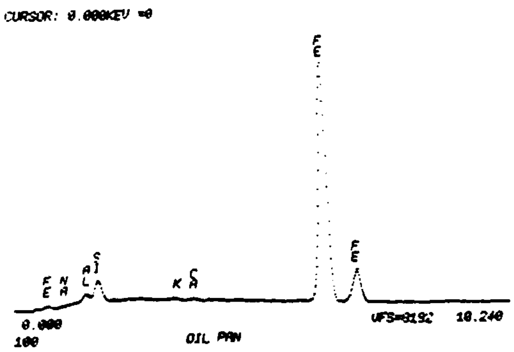


Figure 5.8-2. TRC Failed Component Case History

5.9. Spare Part Storage Inspection

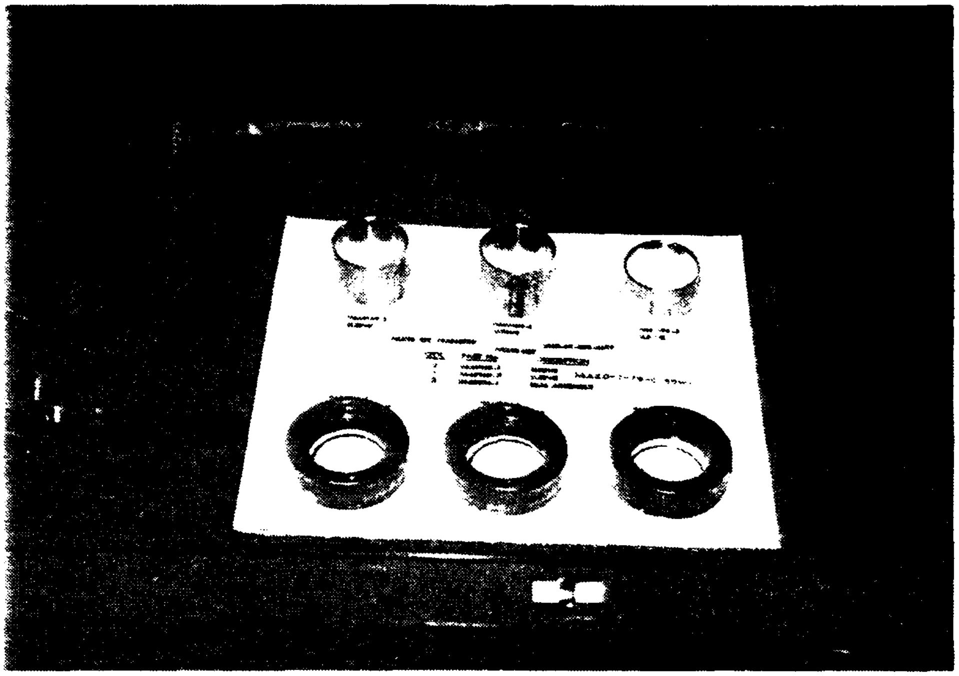
5.9.1. Background. It was reported that replacement parts were frequently received by maintenance units in poor condition relative to corrosion. Instances of "red rust" were frequently reported by lower maintenance levels for parts they had received for installation on vehicles, even though the parts supplied were new replacement parts. Concern over packaging/containers, as well as supply system storage, resulted in inspection of supply system inventories at each vehicle inspection site, i.e., Ft. Ord, California; Schofield Barracks, Hawaii; and Neu Ulm, West Germany. At each site, replacement-part inventories were inspected at several maintenance levels, including the storage or parts in trailers intended for field support activities.

For the most part, replacement component inventories at all maintenance levels were found to be adequate, with only occasional instances of new parts corroding prior to use. The majority of components are received from Original Equipment Manufacturer (O.E.M.) in excellent containers. Vapor barrier paper, foil packs, hermetically sealed containers, and dessicant materials are frequently used. Many critical components, such as gears and bearings, are received from O.E.M. suppliers with a protective coating of grease or oil. Examples of good part protection are shown in Figures 5.9-1, 5.9-2 and 5.9-3.

There were incidents of inventory component corrosion related to the following general categories:

- Outdoor storage of parts;
- Storage and packaging of large components;
- Removal of parts from O.E.M. packaging;
- Rebuilt/repaired component storage;
- Inadequate O.E.M. packaging.

Interviews with maintenance personnel at all locations revealed a common problem: storage space. The higher maintenance levels and rebuild depots had the greatest need for storage space consistent with the expanded nature of repairs performed at this level and corresponding supply system support requirements. Consequently, these higher level maintenance organizations enjoy the largest indoor storage facilities. As the level of maintenance organization is reduced, the nature of repairs performed is also reduced, as is the storage space. It did appear, however, that the



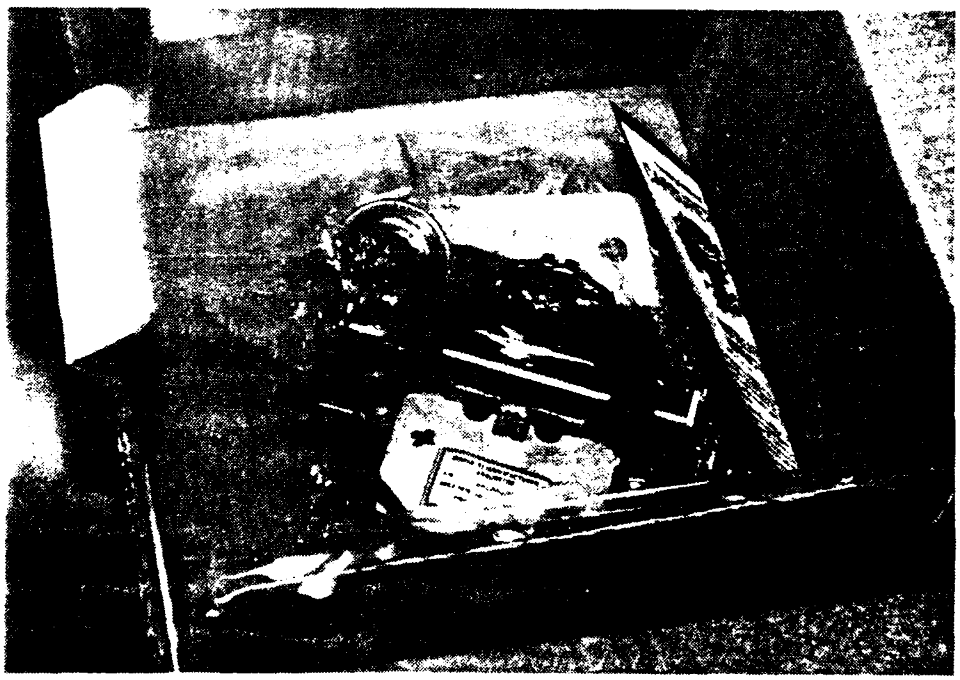


Figure 5.9-1. Clear Plastic Vacuum Packaging

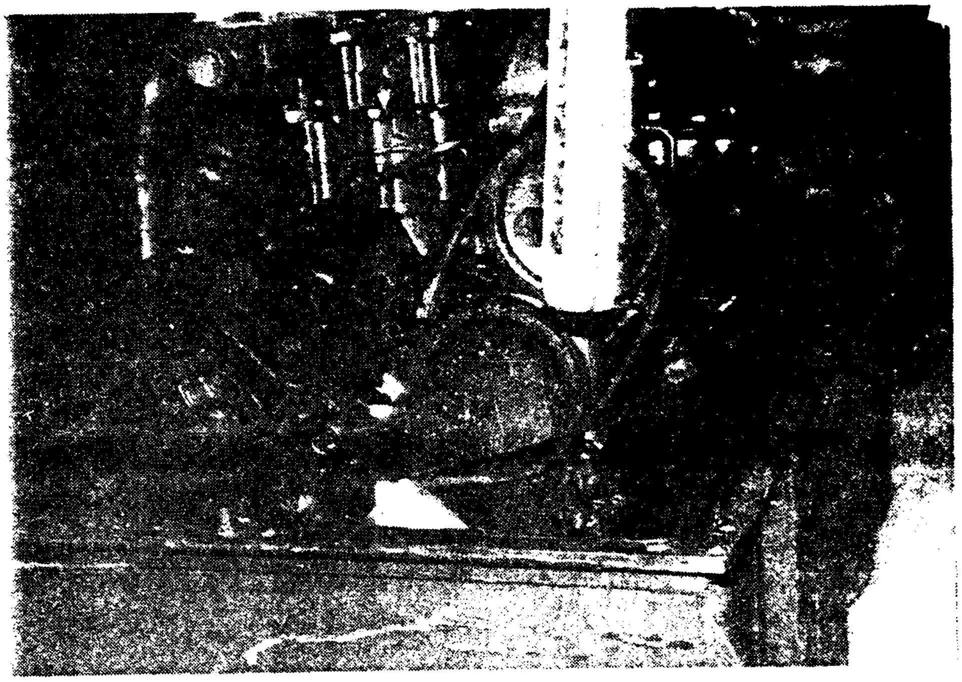


Figure 5.9-2. Engine in Sealed Containers

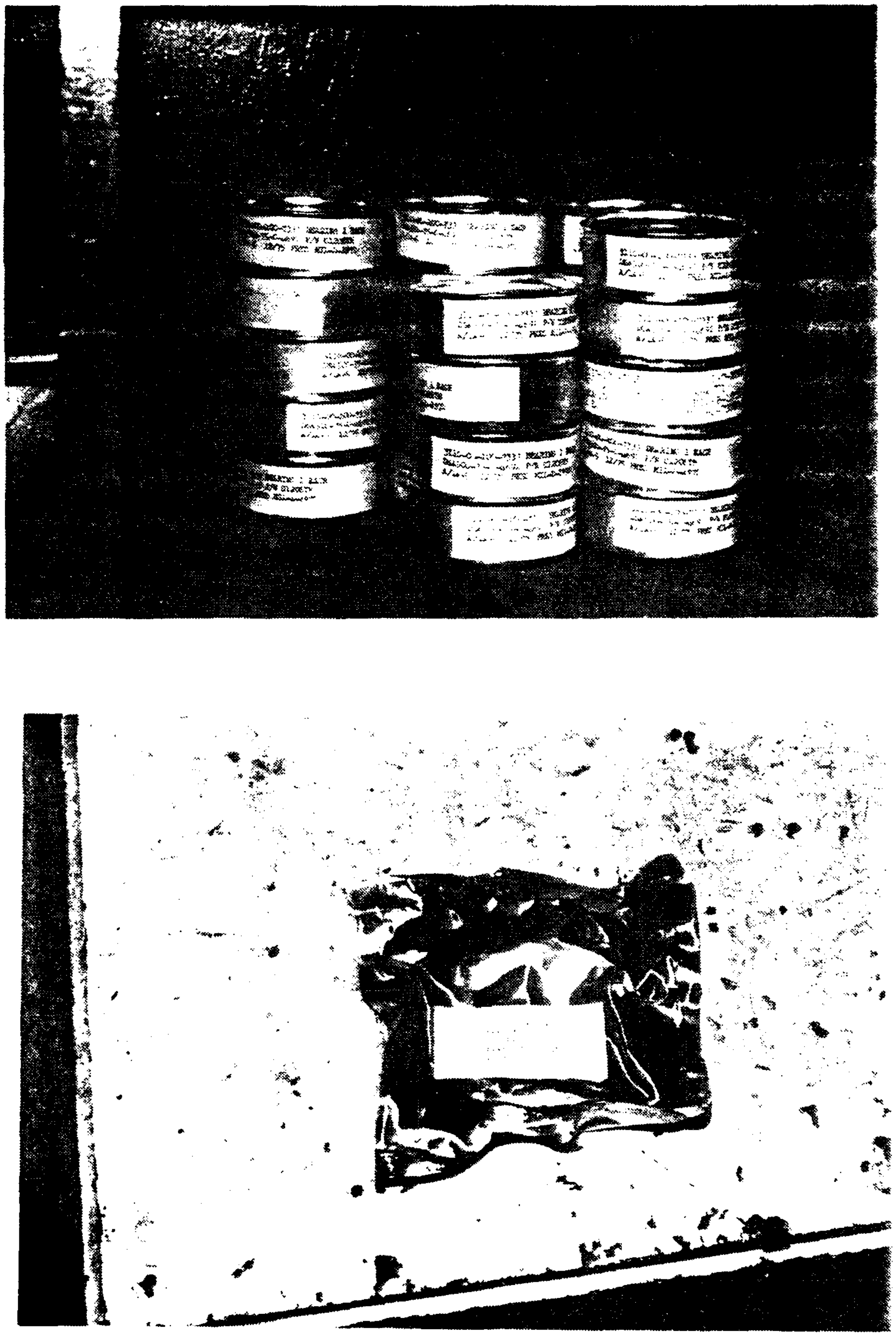


Figure 5.9-3. Sealed Cans or Pouches

reduced amount of storage space was in many cases insufficient for the amount of inventory involved. Consequently, several "space-saving" techniques were employed, several of which are not conducive to component corrosion protection.

5.9.2. Outdoor Storage of Parts. The simplest methods observed of expanding storage space was the use of out-of-doors space. The nature of outside storage varied from temporary cover, in the form of tents or canopies, to no cover whatsoever. Large components such as axles, engine assemblies, body and fender parts, and large suspension components were observed in outdoor storage areas. Cardboard boxes and wooden crates were easily penetrated by moisture and resulted in varying degrees of general surface corrosion and crevice corrosion. Unpackaged parts were found stored on the ground or on wooden pallets. General surface corrosion of these parts were also observed. In addition, outside storage was generally less organized and subject to physical damage in high-traffic areas. Broken containers, metal-to-metal contact resulting in paint chipping, and subsequent corrosion were observed more frequently outside than inside. Some examples of the difficulties associated with outdoor storage are shown below in Figures 5.9-3, 5.9-4, 5.9-5, 5.9-6 and 5.9-7.

5.9.3. Storage and Packaging of Large Components. Difficulties associated with the storage of large parts was not limited to outside storage. Indoor storage of larger parts also presented space, packaging, and corrosion-related problems. Several large components are received from O.E.M. in even larger bulky packaging. Even though this packaging provides some degree of protection, it is often discarded for the purpose of conserving space. External packaging, internal vapor barrier paper, and dessicant materials are also discarded, leaving unpainted surfaces subject to general surface corrosion. This condition is further aggravated in areas of temperate climates and/or close proximity to ocean saltwater.

The parts which have been removed from the package are then stored by stacking them on large racks and shelves without intermediate packing material, resulting in metal-to-metal contact. Such storage results in abrasion or spalling of protective coatings, such as paint or film lubricants, exposing underlying base metal to general atmospheric erosion. Examples of corrosion problems associated with indoor storage of large parts that have been removed from O.E.M. packaging are shown in Figures: 5.9-8 and 5.9-9.

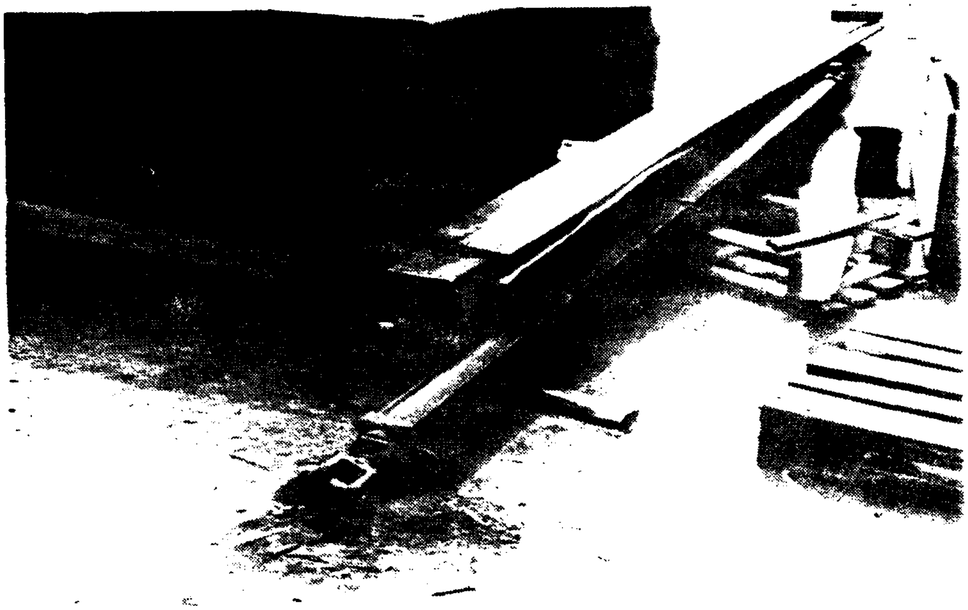
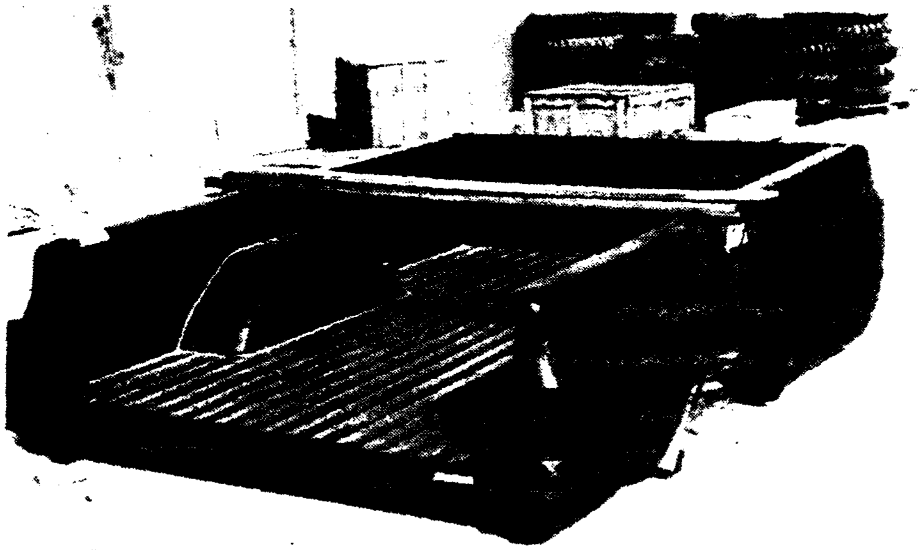


Figure 5.9-4. Damage to Containers and Corrosion of Exposed Components



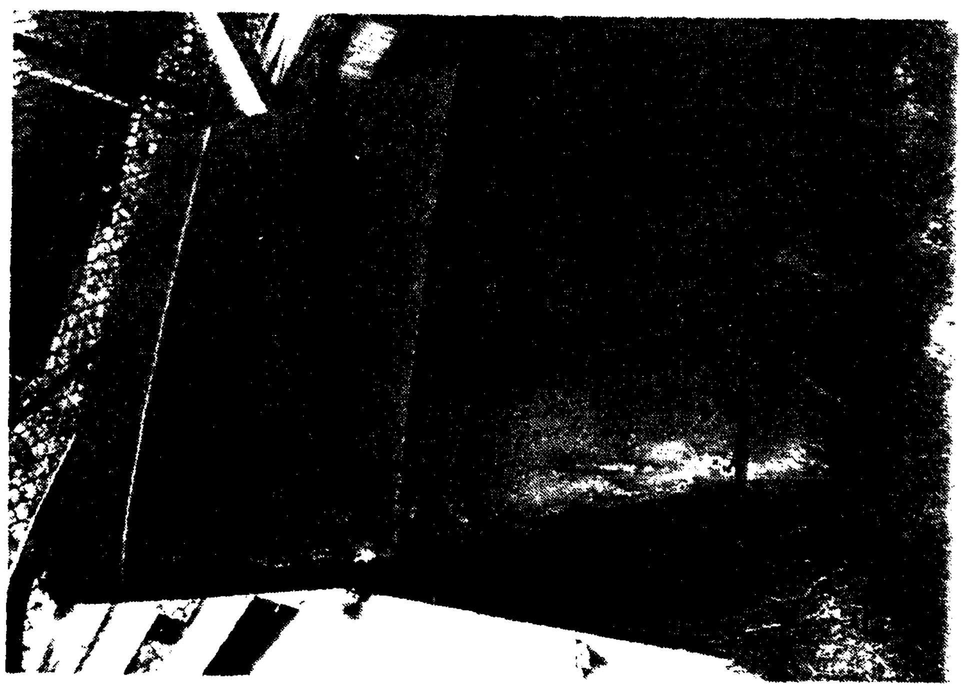
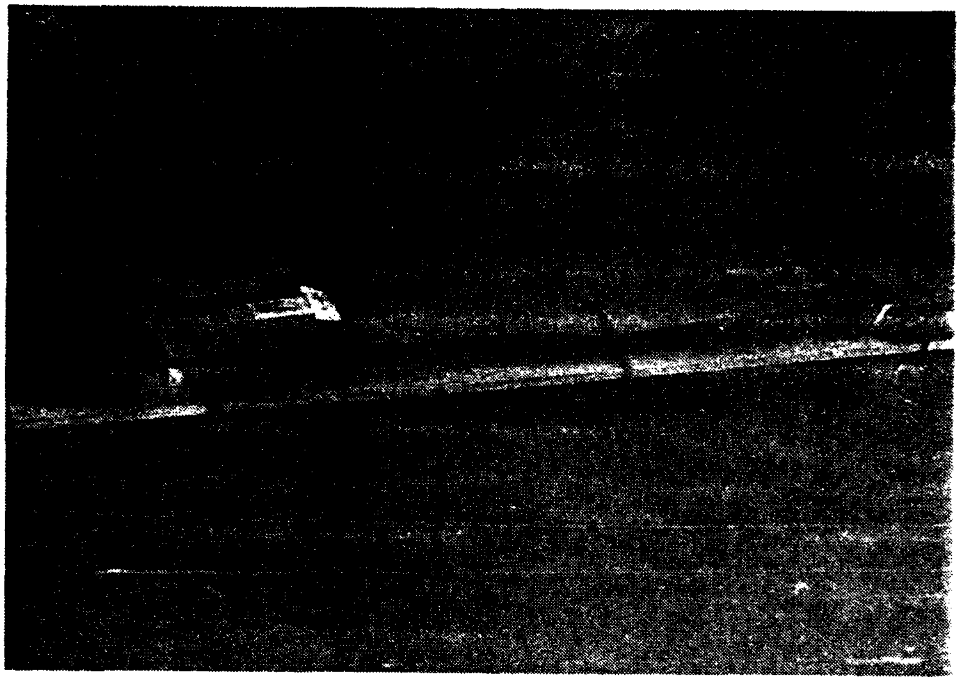


Figure 5.9-5. Outside Storage of Body Components



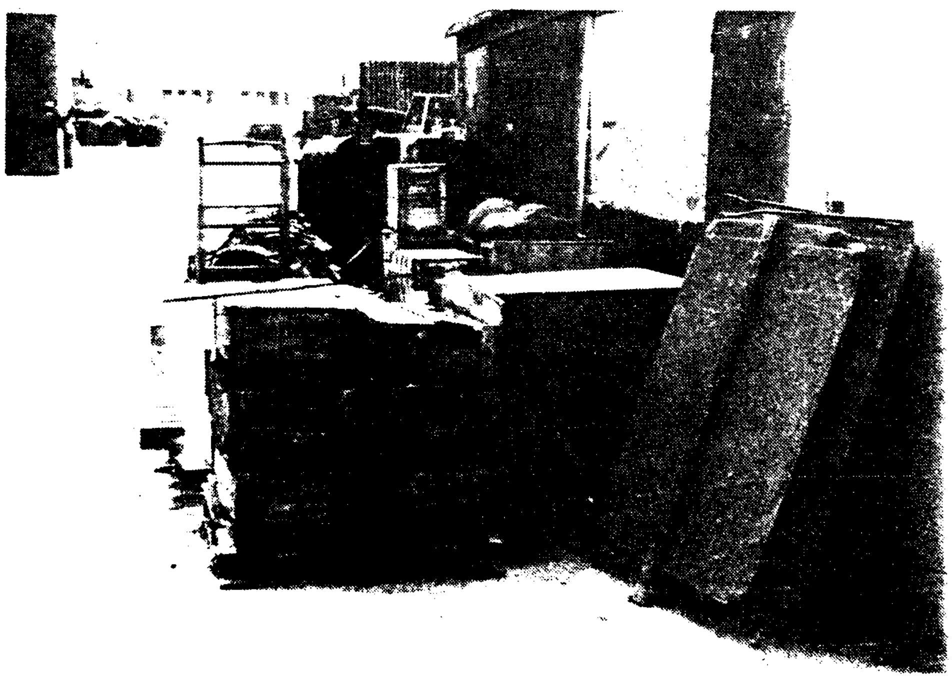


Figure 5.9-6. Outside Storage of Cardboard Containers and Wood Crates

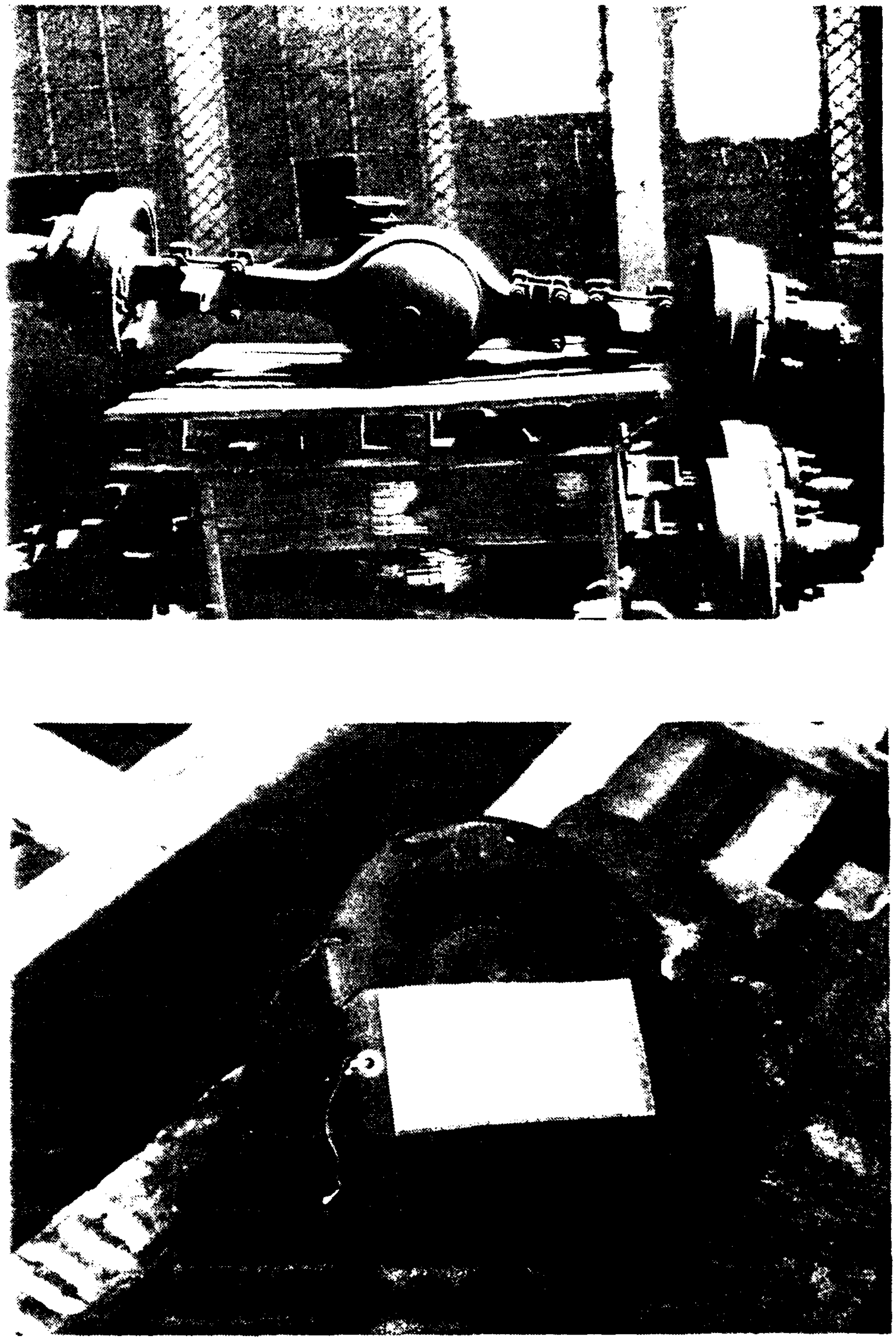


Figure 5.9-7. Outside Storage of Large Components

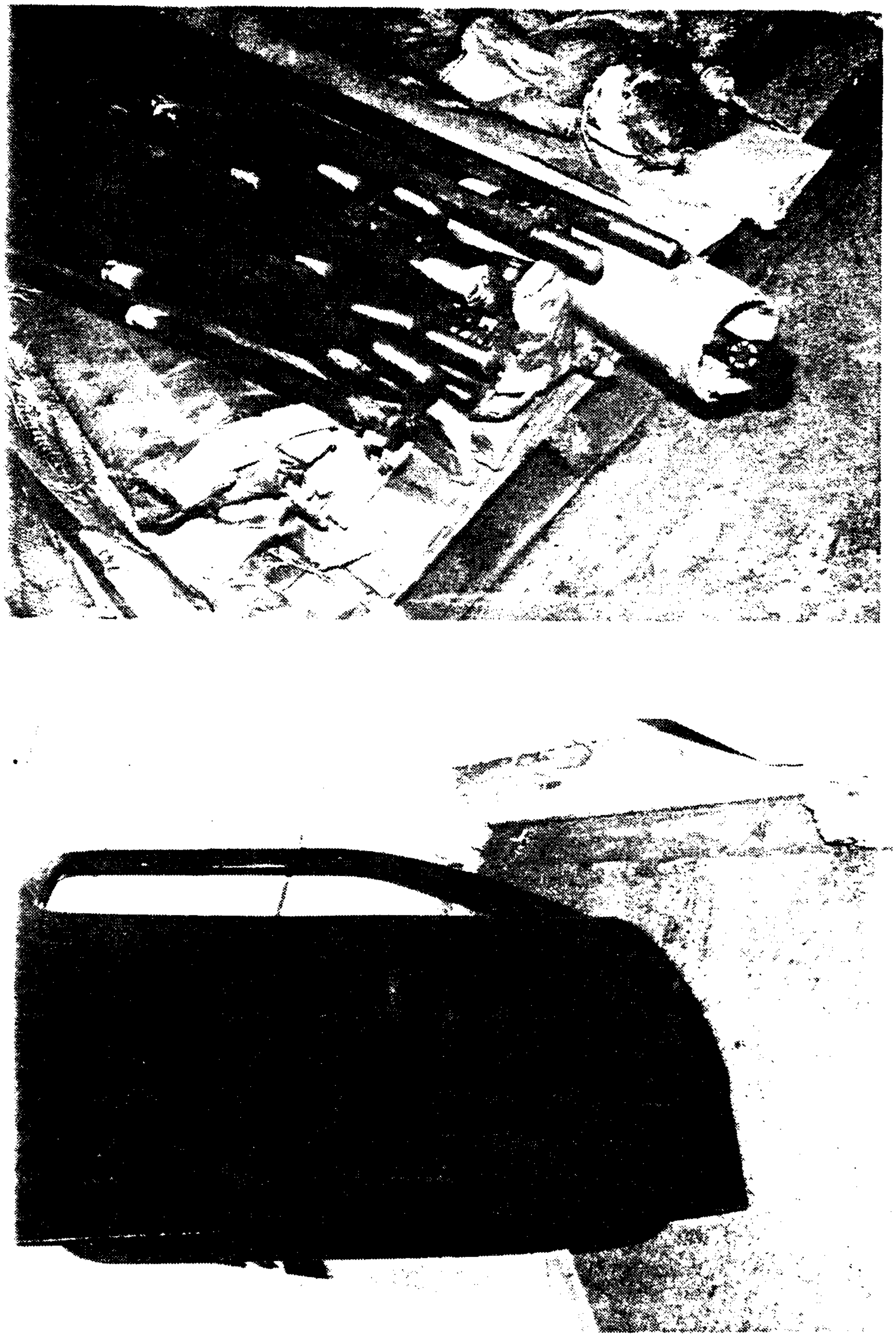


Figure 5.9-8. Indoor Storage of Large Components

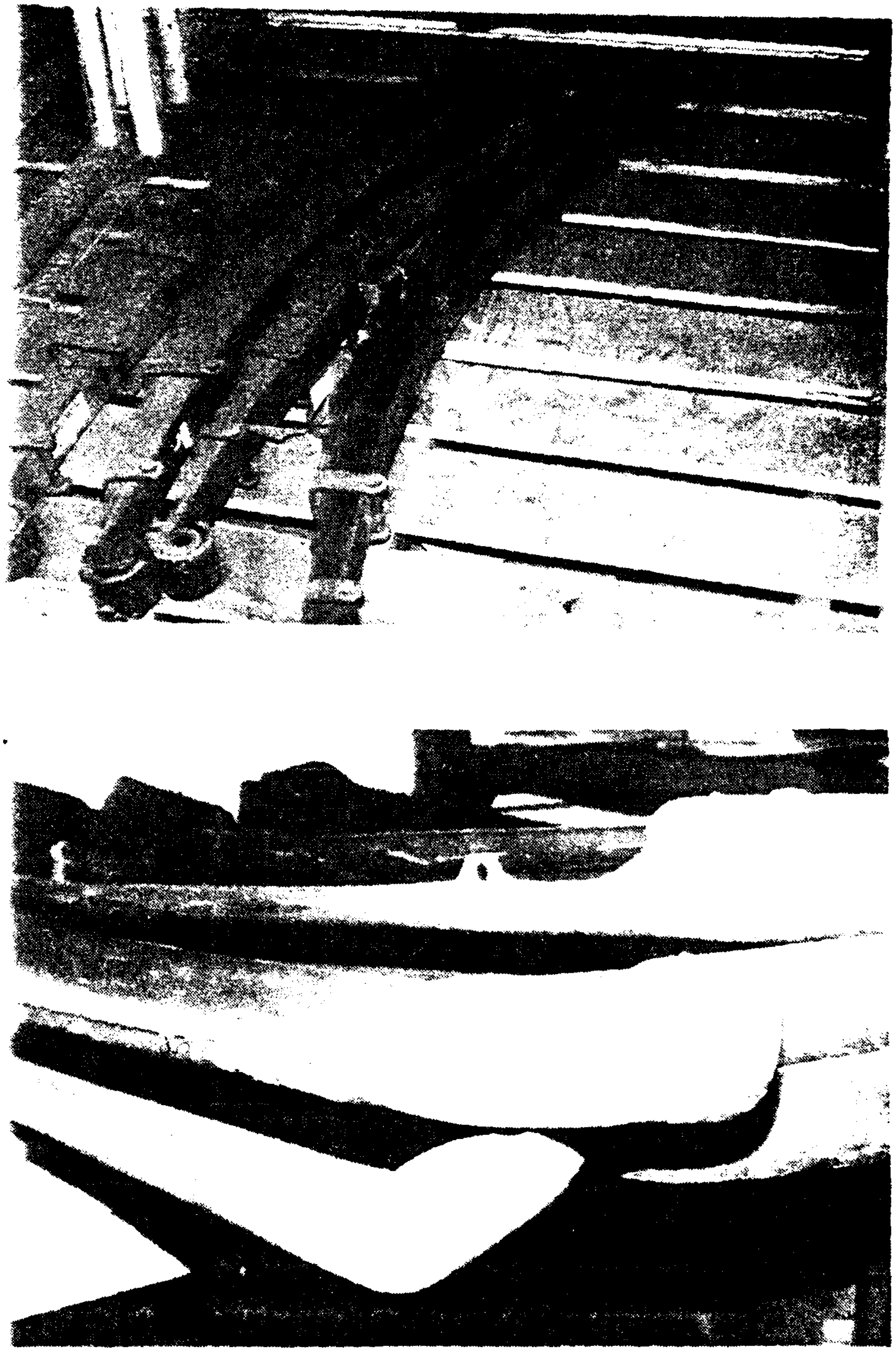


Figure 5.9-9. Indoor Storage of Large Components

5.9.4. Removal of Parts from Original Packaging. Removal of parts from O.E.M. packaging was observed at several supply areas. The three most significant reasons offered for this were: (1) conserving space by breaking down large, bulky packaging (previously discussed); (2) distribution of small quantities of bulk-shipped parts; and (3) the return of incorrectly ordered parts from lower unit levels with packaging removed.

Several small components, such as nuts, bolts, washers, clamps, etc., are received from the O.E.M. in large quantities. The initial packaging is well-suited for corrosion protection. Bulk quantities were shipped wrapped in moisture barrier paper, foil, or plastic sealed. However, once these large quantity packages are received and smaller quantities are dispersed to lower maintenance unit organizations, the parts are delivered without packaging, and the original bulk packaging is destroyed. Examples of initial bulk packaging and redistribution of smaller quantities are shown below in Figures: 5.9-10 and 5.9-11.

It was also observed that parts are occasionally returned from lower level maintenance organizations after the discovery that the wrong part was ordered. Again, as the lower unit level organizations do not have sufficient space to keep unnecessary parts in inventory, they are returned to supply system storage. Parts may have been removed from packaging prior to determining that they were not the correct part numbers. As a result, some parts are then stored without the protective O.E.M. packaging. Side-by-side comparison of packaged with unpackaged parts in inventory demonstrates the need to maintain protective packaging. Examples of general corrosion of unprotected parts in indoor inventory storage are shown below in Figures: 5.9-12 and 5.9-13.

5.9.5. Rebuilt/Remanufactured Components. Various components can be repaired and returned to the supply system for reuse. Many of the repairs on such items as starter motors, alternators, generators, etc., can by performed by maintenance personnel. There appears to be no requirement for repackaging these components. In addition, corrosion of the component is not always addressed during the repair. For example, a rebuilt starter motor that experienced both electrical failure, as well as external corrosion of the housing, may have the failed electrical component replaced without addressing the external corrosion problem.

Used components cannibalized from retired vehicles fall into a similar category. Generally, these parts are checked out functionally and returned to the inventory supply system

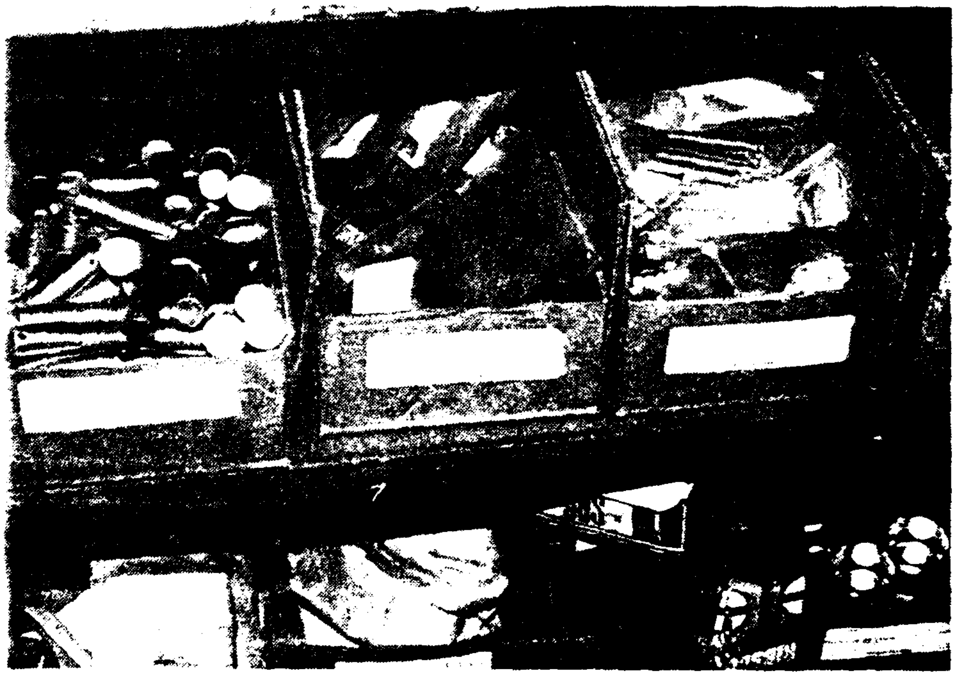


Figure 5.9-10. Typical Bulk Quantity Packaging

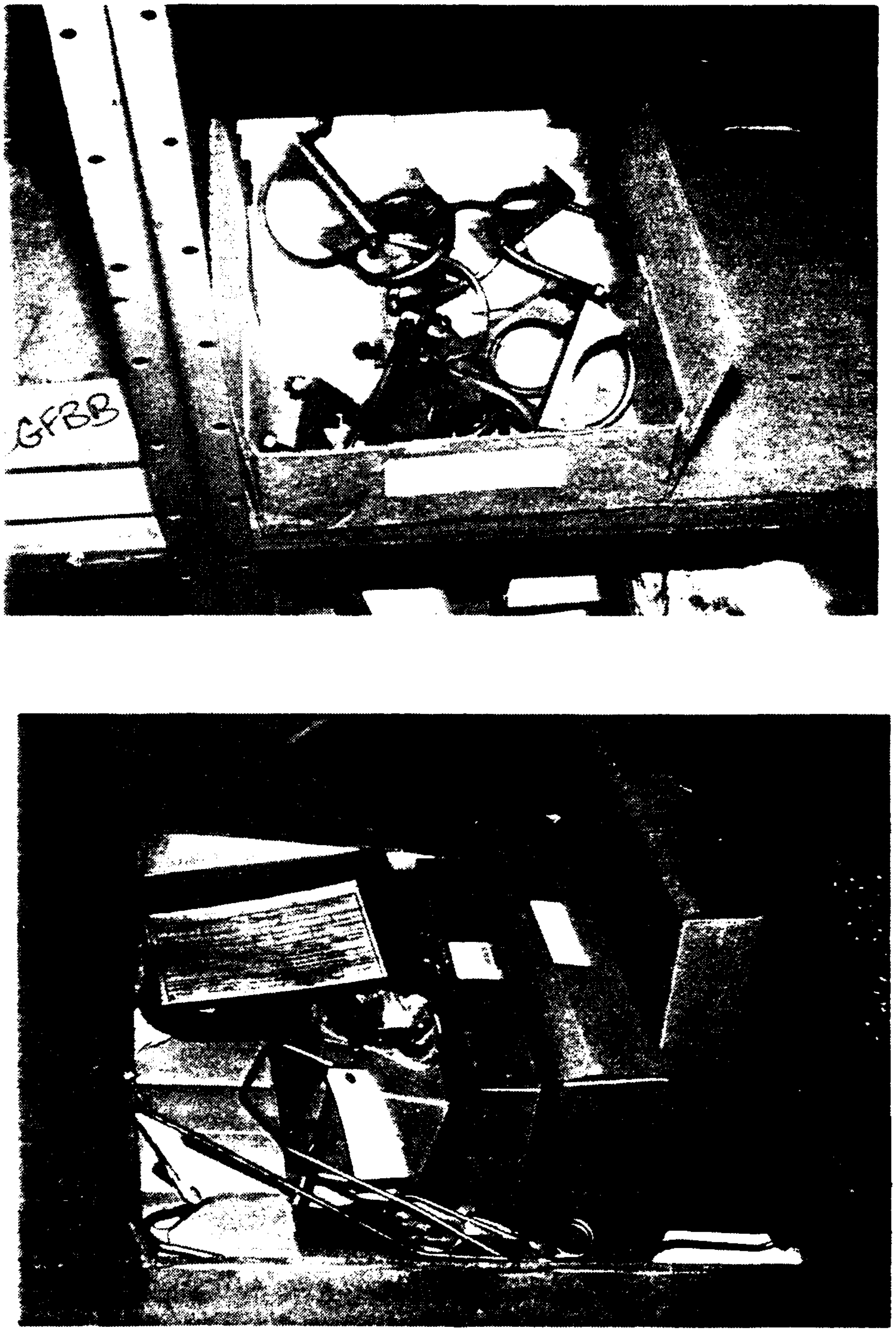


Figure 5.9-11. Redistribution of Bulk Quantity Items

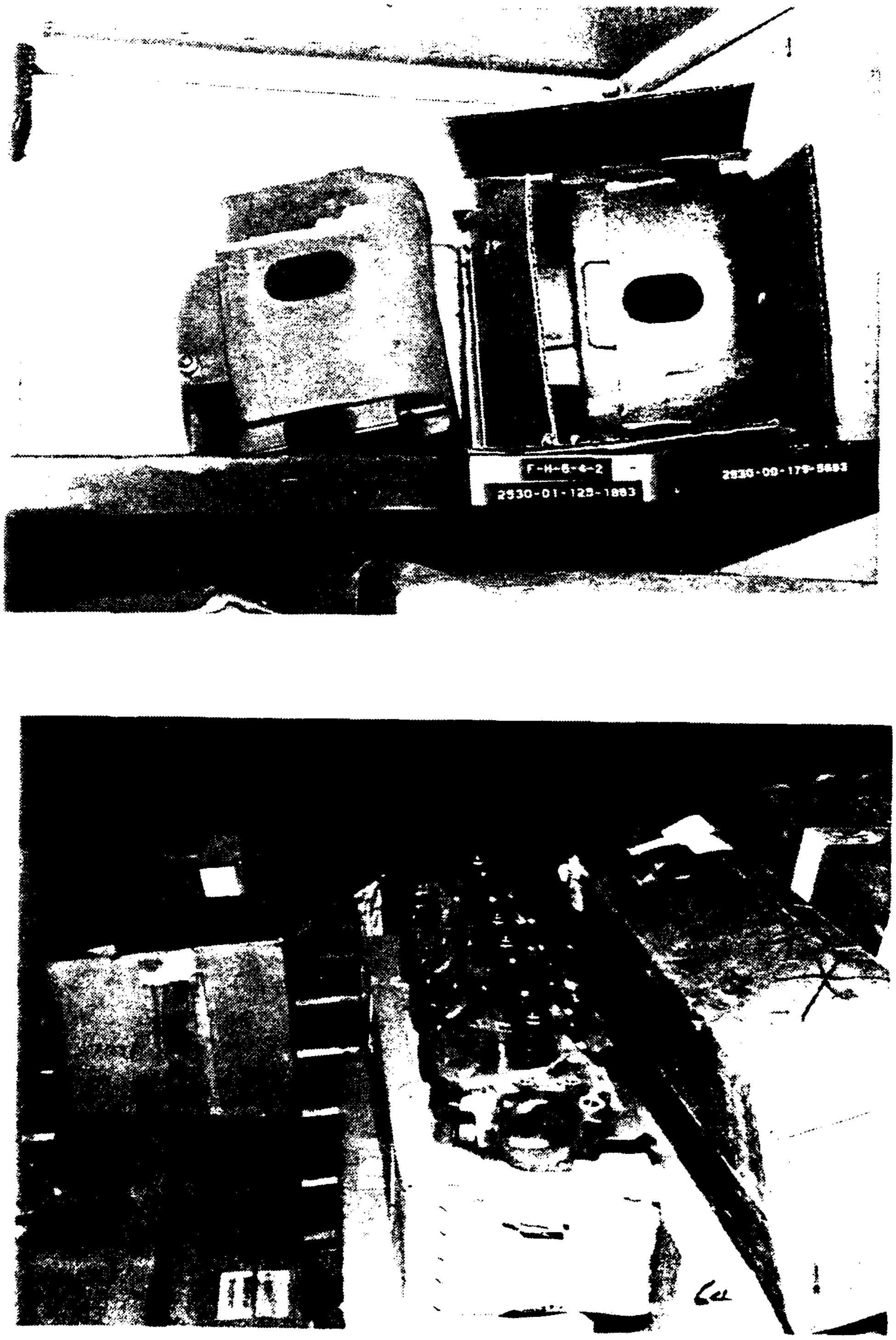


Figure 5.9-12. Parts Returned From Lower Level Maintenance Organizations O.E.M. Packaging Has Been Discarded

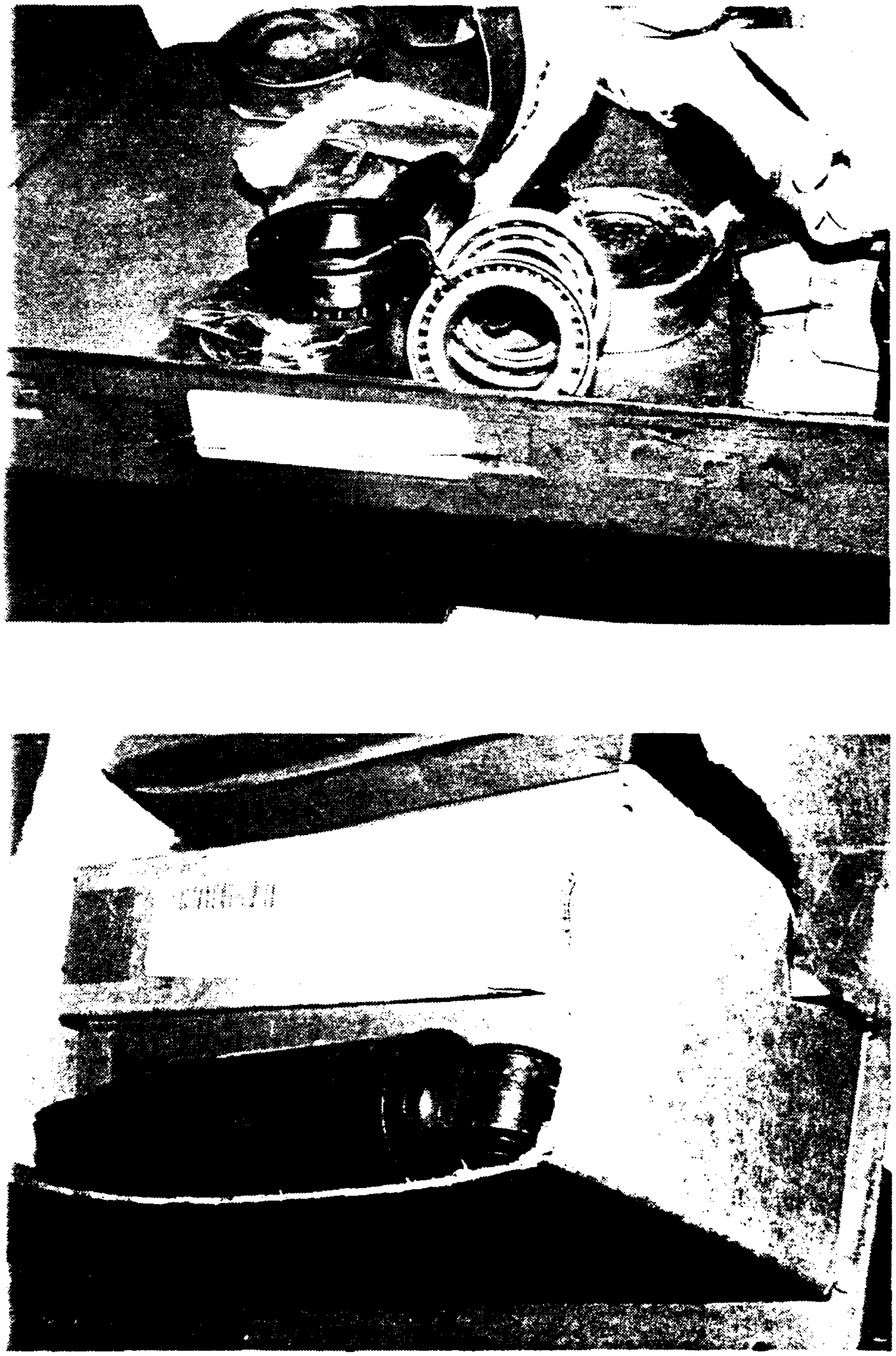


Figure 5.9-13. Parts Returned From Lower Level Maintanenence Organizations O.E.M. Packaging Has Been Discarded

without addressing an associated corrosion problem. Examples of repaired, reconditioned, or used-part inventory storage, without protective packaging, are shown in Figures: 5.9-14 and 5.9-15.

5.9.6. Inadequate O.E.M. Packaging. There were only a few instances where inspection of parts inventories indicated that O.E.M. packaging was inadequate for corrosion protection. Parts received in cardboard containers, without the use of dessicant materials or rust-inhibiting film lubricants, were the most frequently observed example. However, the most predominant packaging failure was the result of some O.E.M. packaging to withstand day-to-day handling. Plastic or vapor barrier paper is easily perforated by parts with sharp corners or edges. Even small perforations admit sufficient moisture to curved bearing or gear surfaces. Hasty wrapping of parts with vapor barrier paper sometimes leaves a portion of the part exposed.

The use of cardboard boxes as a last line of defense against handling damage is marginal. Physical handling damage or the stacking of parts on top of one another often results in torn or otherwise damaged cardboard containers. Metal-to-metal contact with other exposed parts, forklifts, metal shelves, and metal racks may also scratch or chip protective coating or wear away protective film lubricants, resulting in localized corrosion. The most dramatic example of susceptibility to physical damage was broken window glass.

Examples of inadequate O.E.M. packaging and physical damage to packaging are shown in Figures 5.9-16 and 5.9-17.

5.9.7. *Storage Overview and Suggestions.* The previous examples of potential problems related to the packaging, shipping, storage, and handling of parts in the inventory supply system were, overall, infrequent. In general, they were most evident at lower levels of the maintenance organization and, in most cases, affected by the lack of available space. The majority of parts within the supply inventory system were properly packaged for environmental protection. For the instances where difficulties were observed, the following suggestions are offered:

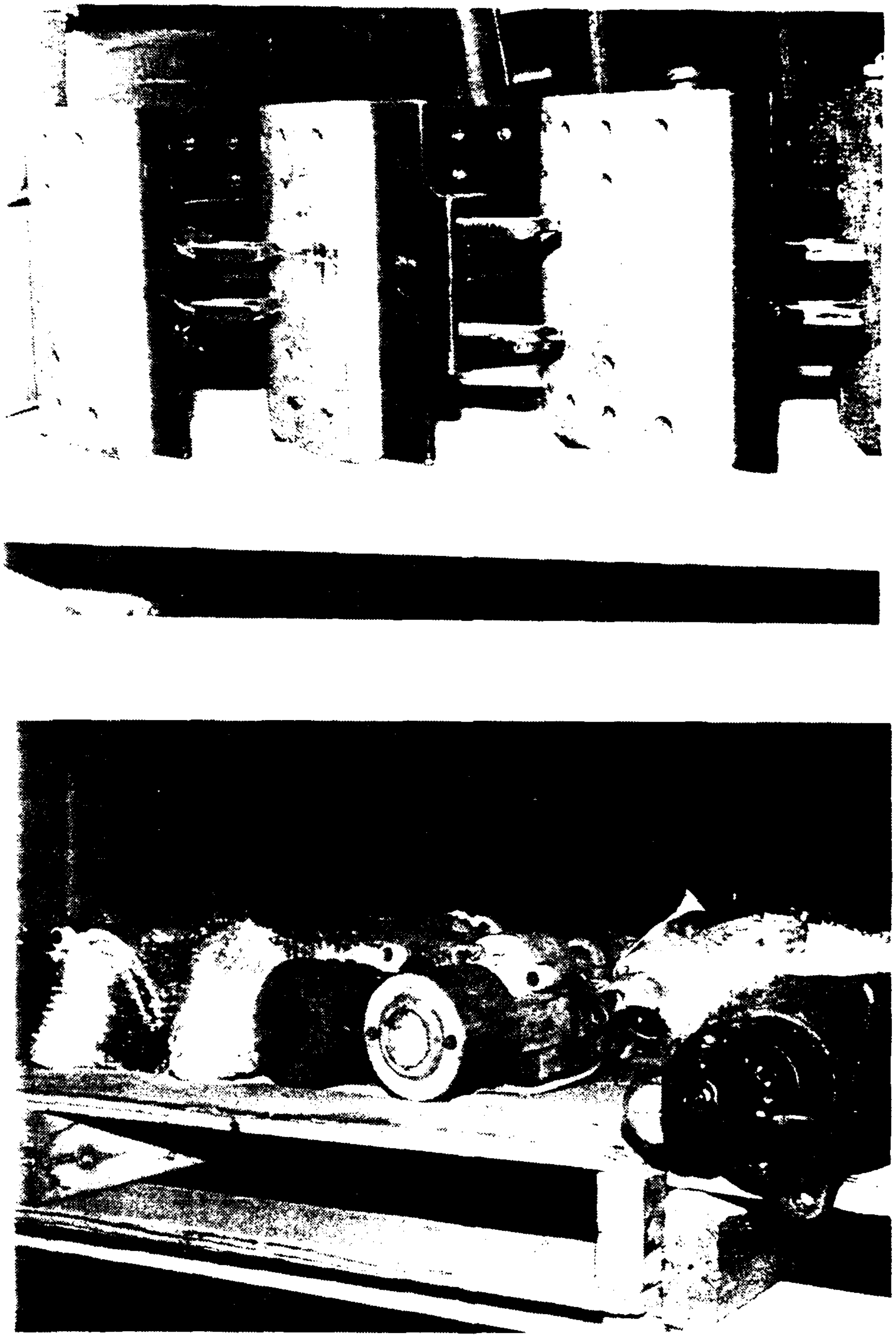
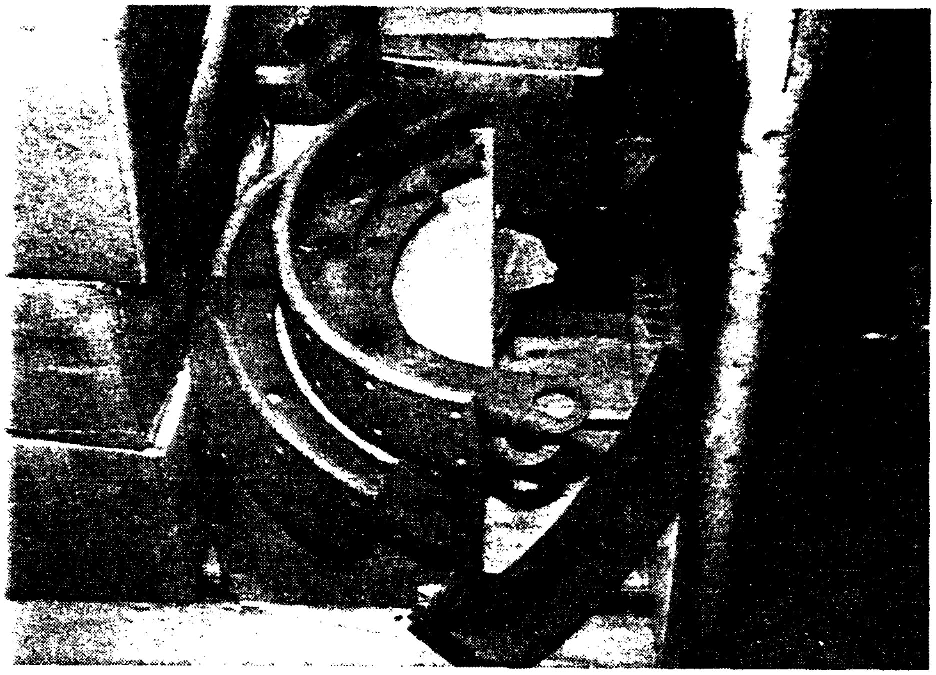


Figure 5.9-14. Remanufactured / Used Parts Without Packaging



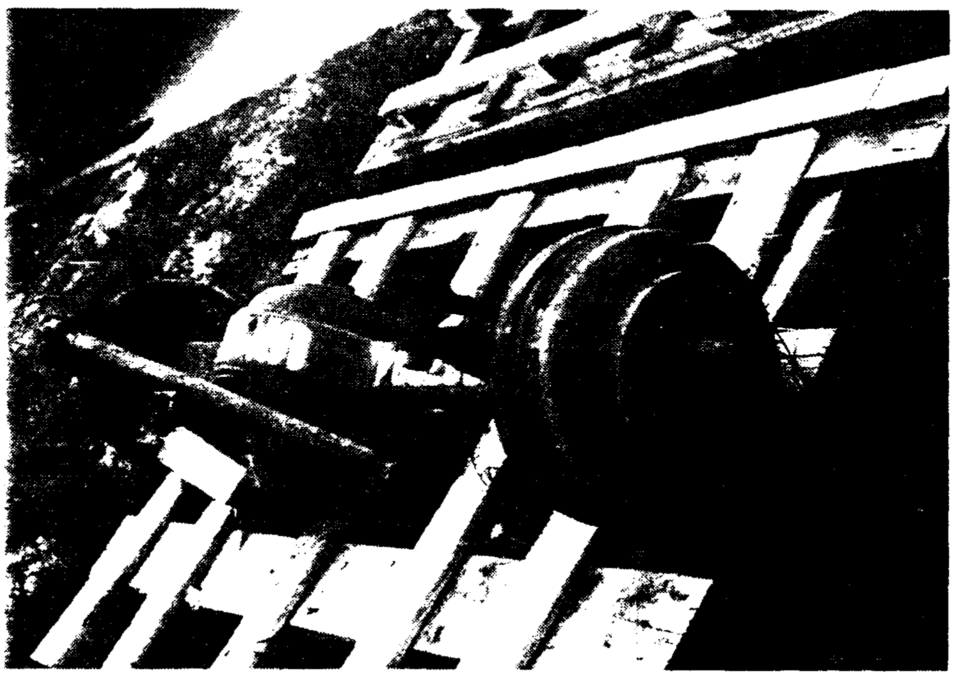


Figure 5.9-15. Rebuilt / Used Parts Without Packaging

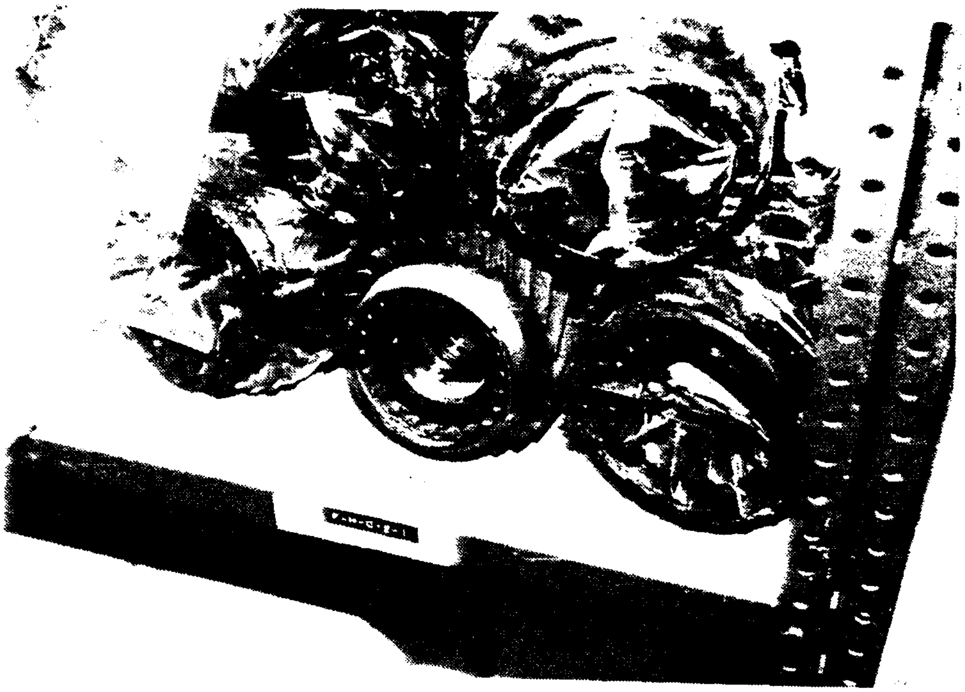


Figure 5.9-16. Inadequate and/or Packaging Damage

Figure 5.9-17. Inadequate and/or Packaging Damage

- Increase indoor storage area. Although square footage is often a problem, improvement in organization of parts inventories can be substantially improved. Make better use of vertical space. Parts spread out on the floor or on pallets consume greater quantities of square footage by comparison to those storage areas that make use of vertical racks, shelves, etc. Organization of this nature will also reduce packaging damage, minimize handling, and save time searching for inventory items.

- Parts that must be committed to outdoor storage should be limited to those items that are properly packaged in moisture-proof containers (such as the hermetically sealed engine containers). Large parts, such as heavy vehicle axles and body parts, should be properly painted before storing in outdoor areas. In addition, it should be kept in mind that the wrong packaging can do more harm than good. Cardboard will absorb moisture and retain it for long periods of time. Fully enclosed wooden containers may not be moisture-proof, but they will inhibit drying of internal moisture on dry days. Circulation of dry air to remove moisture should be kept in mind.

- Establish procedures for repackaging. Components that are ordered in bulk and subsequently broken down for distribution of smaller quantities should be repackaged by supply system personnel. The use of ziplock plastic storage bags by some units was observed to be quite effective in preventing general corrosion of unpackaged parts. This also applied to returned and remanufactured components. Establish requirements for the repackaging of such components.

- Make better use of commercially available spray film lubricants/rust inhibitors, such as WD-40, silicone spray, etc. This is particularly important for bearing, gears, and other internal components that have stringent surface finish and/or dimensional requirements. Perhaps a standard procedure for application of such materials and repackaging could be used throughout the U.S. Army supply system.

- Recirculate unpackaged components first. Although everyone wants to receive bright, shiny, new parts in undamaged containers, avoid the tendency to remove those parts from inventory before recirculating unpackaged parts. Managing the distribution of parts in this manner will quickly reduce the number of unpackaged parts in inventory.

- Include corrosion repair and prevention in the repair and reconditioning of components. Although initial damage will appear to be cosmetic only, corrosion damage is time-dependent and accumulative. Repaint, regrease, oil, etc., reconditioned parts. Apply spray film lubricants when appropriate and require repackaging.

- Separate the storage of vehicle components from the storage of chemicals, acids, and cleaning fluids that may corrode parts in the event of leaks or spillage. Do not store battery acid near critical engine components, for example. Avoid close proximity to potentially corrosive industrial pollution. High sulfur content in the environment from coal dust or power plant emissions can substantially increase acid rain contamination. Choose storage locations wisely.

- Encourage the continued use of sealed containers, vacuum foil packs, vapor barrier paper, dessicant materials, etc., from O.E.M. suppliers. These forms of packaging are working well.

- Discuss potential handling problems that may result in packaging damage with O.E.M. suppliers to encourage further packaging improvements. Consider the possibility of permanent packaging that is reusable at the storage site or returned to the O.E.M. for credit and reuse.

These suggestions are not highly technical, nor should they require extensive cost to incorporate. They will, however, complement the significant improvements that have recently been made in the packaging and storage of U.S. Army Supply System inventories.

APPENDIX A
HMMWV FIELD FAILURE CASE HISTORIES

APPENDIX A: HMMWV FIELD FAILURE ANALYSIS/CASE HISTORY

CASE HIST. NUMBER	PART.#	PART DESCRIPTION	CAUSE OF FAILURE
1	AMA-3010AS	GENERATOR ROTOR ASSM.	mechanical
2	AMA-3010AS	GENERATOR ROTOR SHAFT	mehanical
3	AMA-3010AS	GENERATOR ROTOR ASSM.	mechanical
4	AMA-3010AS	GENERATOR ROTOR ASSM.	mechanical
5	AMA-3010AS	GENERATOR ROTOR	mechanical
6	AMA-3008	STARTER HOUSING	mechanical
7	5590726	GENERATOR BRACKET	mechanical
8	5590726	GENERATOR BRACKET	mechanical
9	5590726	GENERATOR BRACKET	mechanical
10	5590726	GENERATOR BRACKET	mechanical
11	5591018	ENGINE BRACKET	mechanical
12	5591018	ENGINE BRACKET	mechanical
13	5593016	MACHINE BOLT	mechanical
14	5593016	MACHINE BOLT	mechanical
15	5593017	MACHINE BOLT	mechanical
16	5593016	BOLT, MACHINE	mechanical
17	5591680	PULLEY	mechanical
18	5591680	GENERATOR PULLEY	mechanical
19	AMA3008	GENERATOR ASSM.	electrical
20	AMA-2004AS	REGULATOR	electrical
21	AMA-2004AS	REGULATOR	electrical
22	AMA-1002	GENERATOR HEAD	mechanical
23	AMA-2004AS	REGULATOR	unknown

CASE HIST. NUMBER	PART #	PART DESCRIPTION	CAUSE OF FAILURE
24	1059-06607-01	REGULATING VALVE	unknown
25	109413-01	REGULATING VALVE SWITCH	unknown
26	5740226	SHIFTOR FORK	unknown
27	5740116	SHIFTER FORK	mechanical
28	5740092	GEAR SHAFT SPUR	mechanical
29	8625187	FWD CLUTCH HOUSING	mechanical
30	8633257	BAND, TRANS.	mechanical
31	MFY10	STARTER MOTOR BRACKET	unknown
32	SAT-52	COIL SPRING	unknown
33	MBD-2566	STARTER ARMATURE	electrical
34	SAT4108UT	ELEC. SOLENOID	electrical
35	AMA-1015SS	ELEC BRUSH HOLDER	mechanical
36	PS-147555	STARTER HOUSING ASSM.	mechanical
37	DRA-3002D	STARTER SOLENOID DRIVE	mechanical
38	MBP-2566	STARTER ARMATURE	mechanical
39	MFY-1210155	STARTER MOTOR	corrosion
40	297-0027	HALF SHAFT	unknown
41	297-0025	HALF SHAFT	mechanical
42	297-0026	HALF SHAFT	mechanical
43	5568226	ROLLER BEARING	mechanical
44	5740512	SPRACKET WHEEL	mechanical
45	5740515	FRONT OUTPUT YOKE	mechanical
46	5574921	SPUR GEAR	mechanical
47	5574922	LOWER SPUR GEAR	unknown

CASE HIST. NUMBER	PART #	PART DESCRIPTION	CAUSE OF FAILURE
48	277-0027	DIFFERENTIAL JOINT	mechanical
49	106397-01	BRAKE LINING	mechanical
50	B17-09193-A	DISC BRAKE	mechanical
51	104534-01	DISC BRAKE YOKE	mechanical
52	2771301	CYLINDER ASSM.	unknown
53	5578522	HOOD HINGE	corrosion
54	5578522	HOOD HINGE	corrosion
55	10812	WIRE ROPE ASSM.	mechanical
56	A040096268	PARTS KIT STRAP	mechanical
57	5578293	REAR BUMPER BRACE	unknown
58	14082745	WATER PUMP	mechanical
59	8990733	GLOW PLUG	unknown
60	WSU-400-6UT	REMOTE CONTROL SWITCH	electrical
61	WSU-400-6UT	REMOTE CONTROL SWITCH	electrical
62	WSU-400-6UT	REMOTE CONTROL SWITCH	electrical
63	WSU-400-6UT	REMOTE CONTROL SWITCH	electrical
64	WSU-400-6UT	REMOTE CONTROL SWITCH	electrical
65	AMA-1046A	RECTIFIER	electrical
66	AMA-1042AS	RECTIFIER	electrical
67	MFY-1064B	ELEC BRUSH	mechanical
68	MFV-1102S	COMMUTATOR HEAD	mechanical
69	5582766	TIME DELAY RELAY	corrosion
70	AMA-2028BS	RECTIFIER HEAD AND PLATE ASM.	mechanical

CASE HIST. NUMBER	PART#	PART DESCRIPTION	CAUSE OF FAILURE
71	SAT-1004F	SOLENOID CONTACT	electrical
72	11614156	FRONT COMPOSITE LIGHT	corrosion
73	MSST113-1	LIGHT SWITCH	electrical
74	SF5583394	BRAKE WARNING LIGHT	electrical
75	SF5578716	WINDSHIELD WIPER MOTOR	electrical
76	SF5578716	WINDSHIELD WIPER MOTOR	electrical
77	13194	WINDSHIELD WIPER ARM	unknown
78	GG0552	PRESSURE GAUGE	unknown

APPENDIX B
CUCV FIELD FAILURE CASE HISTORIES

APPENDIX B: CUCV FIELD FAILURE ANALYSIS/CASE HISTORIES

CASE HISTORY NUMBER	PART #	PART DESCRIPTION	CAUSE OF FAILURE
79	14077122	THERMOSTAT	unknown
80	14077122	THERMOSTAT	unknown
81	14082745	WATER PUMP	mechanical
82	7838942	HIGH PRESSURE BRAKE	mechanical
83	7838941	HOSE ASSM.	unknown
84	7838942	HIGH PRESS. BRAKE HOSE	mechanical
85	7838941	HIGH PRESS. BRAKE HOSE	unknown
86	7838936	POWER STEERING PUMP	mechanical
87	359917	TRANS. MODULATOR	corrosion
88	359917	TRANS. MODULATOR	corrosion
89	8624198	CLUTCH PLATE ASSM.	mechanical
90	8623150	CLUTCH PLATE	mechanical
91	8623151	CLUTCH PLATE	mechanical
92	8624198	CLUTCH PLATE	mechanical
93	8633257	BAND ASSEMBLY	mechanical
94	6259423	TRANS. FILTER	mechanical
95	LM501349 LM50131	FRONT WHEEL BEARING	unknown
96	LM501349 LM50131	FRONT WHEEL BEARING	mechanical
97	LM104949 LM104911	WHEEL BEARING	unknown
98	LM104911 LM104949	WHEEL BEARING	mechanical

CASE HISTORY NUMBER	PART #	PART DESCRIPTION	CAUSE OF FAILURE
99	M802048	FRONT WHEEL BEARING	mechanical
100	7451155	FRONT PINION BEARING	mechanical
101	7455617	INNER FRONT WHEEL BEARING	mechanical
102	M88010	BEARING	mechanical
103	7451888	BEARING	mechanical
104	M257	FRONT LOCKING	mechanical
105	3977256	DIFFERENTIAL ASSM.	mechanical
106	40955	UNIVERSAL YOKE JOINT	mechanical
107	97271	UNIVERSAL PARTS KIT	mechanical
108	7806140	UNIVERSAL PARTS KIT	mechanical
109	700013L	SPINDLE	mechanical
110	70013L	SPINDLE	mechanical
111	2232073	BRAKE MASTER CYLINDER	unknown
112	2238739	BRAKE CALIPER ASSM.	unknown
113	26159	PRESSURE SWITCH	electrical
114	XAN-250-H	FUEL FILTER	unknown
115	XAN-250-H	FUEL FILTER	electrical
116	XAN-250-H	FUEL FILTER ASSM.	electrical
117	XAN-250-H	FUEL FILTER ASSM.	unknown
118	24270	FUEL FILTER HEATER	unknown
119	24269	SENSOR SWITCH	electrical
120	14079057	FRONT SEAT BELT	unknown
121	1407958	FRONT SEAT BELT	unknown

CASE HISTORY NUMBER	PART #	PART DESCRIPTION	CAUSE OF FAILURE
122	6273948	FRONT INNER SEAL	unknown
123	8629531	FRONT BAND ASSM.	unknown
124	14026804	STEERING TIE ROD	mechanical
125	8623174	REAR SERVO GASKET	mechanical
126	8629227	GOVERNOR ASSM.	mechanical
127	327011	REGULATOR	unknown
128	14027431	DOOR WINDOW REGULATOR	mechanical
129	14072497	REAR WINDOW CRANK	mechanical
130	14079401	PISTON	mechanical
131	14025523	CONNECTING ROD	mechanical
132	14050718	RING SET	mechanical
133	14079401	PISTON	mechanical
134	14025523	CONNECTING ROD	mechanical
135	14079402	PISTON	mechanical
136	14079401	PISTON	mechanical
137	14079401	PISTON	mechanical
138	14050718	RING SET	unknown
139	14025526	CONNECTING ROD BOLT	unknown
140	14033928	EXHAUST VALVE	unknown
141	14066246	HEAD GASKET	unknown
142	14050425	FUEL PUMP PUSH ROD	mechanical
143	14077157	FLYWHEEL	mechanical
144	14077157	FLYWHEEL	mechanical

CASE HISTORY NUMBER	PART #	PART DESCRIPTION	CAUSE OF FAILURE
145	14077157	FLYWHEEL	mechanical
146	14077157	FLYWHEEL	mechanical
147	1985567	STARTER MOTOR HOUSING	mechanical
148	1985564	STARTER DRIVE GEAR ASSM.	mechanical
149	1960908	STARTER MOTOR BOLT	mechanical
150	14077157	FLYWHEEL	mechanical
151	14077157	FLYWHEEL	mechanical
152	1985567	STARTER MOTOR HOUSING	mechanical
153	14028930	STARTER MOTOR MOUNTING POST	mechanical
154	14028930	STARTER MOTOR MOUNTING BOLT	mechanical
155	14067717	GENERATOR MOUNTING BOLT	unknown
156	1986473	FIELD COAL	unknown
157	1978875	GENERATOR ROTOR	mechanical
158	14072334	MARKER LIGHT	corrosion
159	14072332	MARKER LIGHT	mechanical
160	12258221	BLACKOUT HEADLAMP	corrosion
161	22029595	WINDSHIELD WIPER MOTOR	unknown
162	12034592	CIRCUIT BOARD	electrical
163	14076947	RESISTOR	unknown
164	12039269	BATTERY CABLE	mechanical
165	356284	RELAY	mechanical
166	14076885	RELAY	electrical

CASE HISTORY NUMBER	PART #	PART DESCRIPTION	CAUSE OF FAILURE
167	14076885	RELAY	electrical
168	14076885	RELAY	electrical
169	14076885	RELAY	electrical
170	14076885	RELAY	electrical
171	5613939	GLOW PLUG	unknown
172	5613939	GLOW PLUG	unknown
173	5613939	GLOW PLUG	unknown
174	5613939	GLOW PLUG	unknown

APPENDIX C
5-TON FIELD FAILURE CASE HISTORIES

APPENDIX C: 5-TON FIELD FAILURE ANALYSIS/CASE HISTORIES

CASE HIST. NUMBER	PART #	PART DESCRIPTION	CAUSE OF DEFECT
175	229752376	Brake Adjusting Plunger	unknown
176	M535387-1	Reflector	mechanical
177	12256012-2	Fire Wall	corrosion
178	204587	Oil Dipstick Tube	mechanical
179	12255901	Hood Angle Bracket	mechanical
180	12256629-1	Hood Support	corrosion
181	11669163	Hood Clasp	mechanical
182	8741446	Headlight Retaining Ring	corrosion
183	7373276	Cab Door Lock	corrosion
184	7373289	Window Regulator	unknown
185	11669206	Hose Assembly	unknown
186	2256030-2	Frame Support	mechanical
187	7409596	Pillar Post	corrosion
188	11668932	Blackout Lamp	corrosion
189	11639541	Composite Light	corrosion
190	11639541	Composite Light	corrosion
191	MS-35422-1	Clearance Light	corrosion
192	7413447	Seal	unknown
193	7979349	Seal	mechanical
194	7979349	Seal	mechanical
195	11669023	Seal	mechanical

CASE HIST. NUMBER	PART #	PART DESCRIPTION	CAUSE OF DEFECT
196	130240	Water Pump Gasket	mechanical
197	AR-04284	Water Pump	mechanical
198	AR-04284	Water Pump	mechanical
199	20X-1336	Wheel Stud	mechanical
200	9422961	Machine Bolt	mechanical
201	22-W-162-100-28	Retaining Wire	mechanical
202	7952641	Flexable Shaft	mechanical
203	6834374	Clutch Disc	mechanical
204	6834348	Clutch Disc	unknown
205	6834370	Clutch Plate	unknown
206	6835687	Clutch Disc	unknown
207	6834348	Clutch Disc	unknown
208	23013789	4th Clutch Assm.	mechanical
209	7346991	Companion Flange	unknown
210	11664542-1	Steering Propellor Shaft	mechanical
211	7346895	Seal Cover Assm.	mechanical
212	387AS-382A	Bearing	mechanical
213	MS19081	Bearing	mechanical
214	AMA2004AS	Regulator	corrosion
215	AMA2004AS	Regulator	electrical
216	AMA1002	Rectifier Head	mechanical
217	78218	Alternator Rotor	mechanical

CASE HIST. NUMBER	PART #	PART DESCRIPTION	CAUSE OF DEFECT
218	10929868	Generator Rotor	mechanical
219	11669322	Pulley	unknown
220	11669322	Pulley	unknown
221	79390	Starter Armeture	mechanical
222	11669618-1	Wiper Motor Assm.	unknown
223	11669618-1	Wiper Motor Assm.	mechanical
224	11669618-1	Wiper Motor Assm.	mechanical
225	73733271-1	Windshield Arm	unknown
226	11669105	Valve Assm.	corrosion
227	11669105	Valve Assm.	corrosion
228	A1-2797-B-418	Plunger/Seal	mechanical
229	2297N3212	Brake Seal Plunger	mechanical
230	A-3261-D-290X	Transfer Interlock	corrosion
231	244437	Treadle Valve Spring	corrosion
232	10900089	Power Shaft	mechanical
233	8758273	Dust Boot	mechanical
234	7728814	Intervehicle Cable	electrical
235	AMA2004AS	Heat Sink	electrical
236	M13486-1-9	Wire Cable	mechanical
237	11669142	Warning Control	electrical
238	11609301	Pressure Switch	unknown
239	11669414-1	Pressure Switch	electrical

CASE HIST. NUMBER	PART #	PART DESCRIPTION	CAUSE OF DEFECT
240	11669414-1	Pressure Switch	corrosion
241	P9062-102	Pressure Switch	unknown
242	102837	Control Valve	corrosion
243	F-1680-12	Cluster Valve	unknown
244	12258931-1	Tachometer Drive	corrosion
245	11613632	Signal Control	electrical
246	M535746-1	Coupling	mechanical
247	M5500040-6	Liquid Transmitter	mechanical
248	12269868	Fiber Rope	corrosion

APPENDIX D
TRC FIELD FAILURE CASE HISTORIES

APPENDIX D. TRC TEST VEHICLE FAILURE ANALYSIS CASE HISTORIES

CASE HIST. NUMBER	PART#	PART DESCRIPTION	CAUSE OF FAILURE	AGE EQUIV. IN YRS.
T1	5591170	Headlight Assembly	Corrosion	7.5
T2	5590273	Front Marker Lt.	Corrosion	9
T3	MS-5471	Horn	Corrosion	11.5
T4	6442160	Power Steer. Pump	Corrosion	13
T5	6442160	Fuel Pump	Corrosion	10.6
T6	5579436	Differential Cover	Corrosion	9.5
T7	5582414	Retainer Straps	Corrosion	9
T8	5579198	Torque Converter Cover	Corrosion	12.5
T9	5588022	Oil Pan	Corrosion	11
T10	11050-3805	Oil Pan Bolts	Corrosion	11
T11	5583649	Trans. Cooler Lines	Corrosion	10
T13	914201-2626	Front Propeller Shaft Bolts	Corrosion	12
T14	914202-	Propeller Shaft	Corrosion	10
T15	5593817	Differential Hub	Corrosion	10.5
T16	5740575	Propeller Yoke	Corrosion	12
T17	5577659	Parking Brake Rotor	Corrosion or Mechanical	3
T18	5577659 D40-09102	Parking Brake Rotor/Caliper	Corrosion or Mechanical	14
T19	15480200	Parking Brake Cable	Corrosion	11.8

CASE HIST. NUMBER	PART#	PART DESCRIPTION	CAUSE OF FAILURE	AGE EQUIV. IN YRS.
T20	5578371	Brake Pressure Switch	Corrosion	13.5
T21	5590641	Rear Brake Line	Corrosion	15
T22	5578522	Hood Hinge	Corrosion or Mechanical	5
T23	5584966	Hood Latch	Corrosion	11.6
T24	L-20-MA-132-A-11	Steering Pivot Arm	Corrosion	14.5
T25	70112	Rear Shock	Corrosion	8.6
T26	5579618	Rear Cross Member	No Failure Corrosion	15
T27	5594566	Frame Rail	No Failure Corrosion	15
T28	19711-N	Muffler Pipe/ Flange	Corrosion	12.5
T29	5590658	Tail Pipe Clamp	Corrosion	10.6
T30	5582604	Heat Shield	Corrosion	10.6
T31	5584049 5578589	Drive Adapter Speedometer Cable	Corrosion	11.8
T32	5575877	Cargo Tie Downs	No Failure Corrosion	15
T33	5590522	Floor Section	No Failure Corrosion	15
T34	5594105	Accelerator Rod Level	Corrosion	10.6
T35 Mechanica	5595665	Seat Belt 12.2	Corrosion or	
T36	5585220	Air Grille	Corrosion	7.5
T37	5585150	Mirror Arm Assm.	Corrosion	11

CASE HIST. NUMBER	PART#	PART DESCRIPTION	CAUSE OF FAILURE	AGE EQUIV. IN YRS.
T38	---	Floor Section	No Failure Corrosion	15
T39	5575753	Right Front Seat Back	Corrosion	15
T40	5581348	Left Door Assembly	Corrosion	7.5
T41	RTCO-2619	Heater Control Valve	Corrosion	10
T42	5584455	Heater Control Cable	Corrosion	10

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